1994

A geophysical investigation of the Arroyo Seco area Monterey County, California

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A GEOPHYSICAL INVESTIGATION
OF THE ARROYO SECO AREA
MONTEREY COUNTY, CALIFORNIA

A Thesis

Presented to

The Faculty of the Department of Geology

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree of

Master of Science

by

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December 1994

UMI Number: 1361225

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ABSTRACT

A GEOPHYSICAL INVESTIGATION
OF THE ARROYO SECO AREA MONTEREY COUNTY, CALIFORNIA

by David J. Welch

A geophysical investigation using gravity techniques was completed in Arroyo Seco near Greenfield, California to determine the geologic structure of the area. Results from this investigation suggest the presence of a buried fault, southeast of the Sierra de Salinas, extends to the Monroe Swell oil field. Analysis of a gravimetric model of the Salinas Valley indicates a westward sloping basement surface begins near the granitic outcrops of the Gabilan Range. A transition in the sloping basement is located near the Arroyo Seco gorge where the gradient decreases and reverses direction to form a small gravity high north of the Monroe Swell oil field. The gravity high may have formed along a splay fault of the nearby Reliez fault system that coincides with a lineation of six earthquake epicenters and faulting within the southern end of the Sierra de Salinas. The occurrences of earthquakes suggest that the fault is active.

ACKNOWLEDGMENTS

I would like to acknowledge those who patiently supported me through graduate school and this thesis project. Many thanks goes to Dr. John P. Brooke, Dr. Donald L. Reed, and Mr. Jeremy C. Wire for their support, guidance, and advice. Thanks goes to Ms. Karen Swett for her advice and to Mr. J. Brett Calhoun, Mr. Robert Foster, and Mr. John Vernon for their assistance in the field. Finally, I would like to thank my family and friends who encouraged me to finish.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

INTRODUCTION

Purpose and Scope

A geophysical investigation of the Arroyo Seco area was completed near the City of Greenfield, Monterey County, California between 1991 and 1992. The purpose of the study was to use gravity techniques to investigate the Arroyo Seco area in an attempt to reveal subsurface discontinuities and to determine the geologic structure of the region. The study utilized a combined microgravity and regional gravity survey approach to site investigation. The survey results were combined with information regarding the regional geology, earthquake seismicity, and oil exploration data in order to develop a detailed subsurface model of the Arroyo Seco area.

Location, Water Resources, and Climate

Location

The area is located within the Salinas Valley southeast of the Sierra de Salinas (Figure 1). The study area encompasses the Salinas Valley beginning at a point 3.2 km (2 mi) southwest of the Arroyo Seco Bridge along Arroyo Seco Road and 3.2 km (2 mi) northeast of Greenfield at the Salinas River. The Arroyo Seco area is characterized by a large gorge opening and wash extending into the Salinas Valley from the southern end of the Sierra de Salinas. The floor of the gorge opening is covered by young and old alluvium concealing older sediments and pre-Tertiary age rocks. Almost all the pre-Pliocene sedimentary rocks have undergone deformation and are folded and faulted on the west side of the Salinas Valley floor (Dibblee, 1974, and Durham, 1970).

Water Resources

The Arroyo Seco area is a large watershed as well as a tributary to the Salinas River. The Arroyo Seco watershed contains 681 km^2 (263 mi^2) of mountainous area and 104 km^2 (40 mi^2) of valley floor (CH2M Hill, 1982). The watershed was estimated to contribute an average of 144,800,000 m^3 per year (117,400 acre-ft per year) of surface water through the Greenfield dam gage station (CH2M Hill, 1982). This water resource has been has been the focus of a number of Monterey County Water Resource Management Agency studies, one of which examined the feasibility of constructing a dam site near the location of the Arroyo Seco Bridge. Permeable alluvial materials along the Arroyo Seco make this area an attractive percolation basin for ground water recharge and storage. Serious ground water problems caused by overpumping have resulted in sea-water intrusion into the Monterey Bay coastal aquifers. The threat of continued sea water intrusion combined with overpumping of aquifers in other parts of the valley will probably renew interest in Arroyo Seco's water resources.

Climate

The climate of the Salinas Valley is mild and breezy with foggy days and nights. The mean annual precipitation through the mountain ranges varies from 152.4 cm (60 in) in the Santa Lucia Range to 50.8 cm (20 in) in the Gabilan Range (Boyle Engineering, 1986). Precipitation in the valley averaged

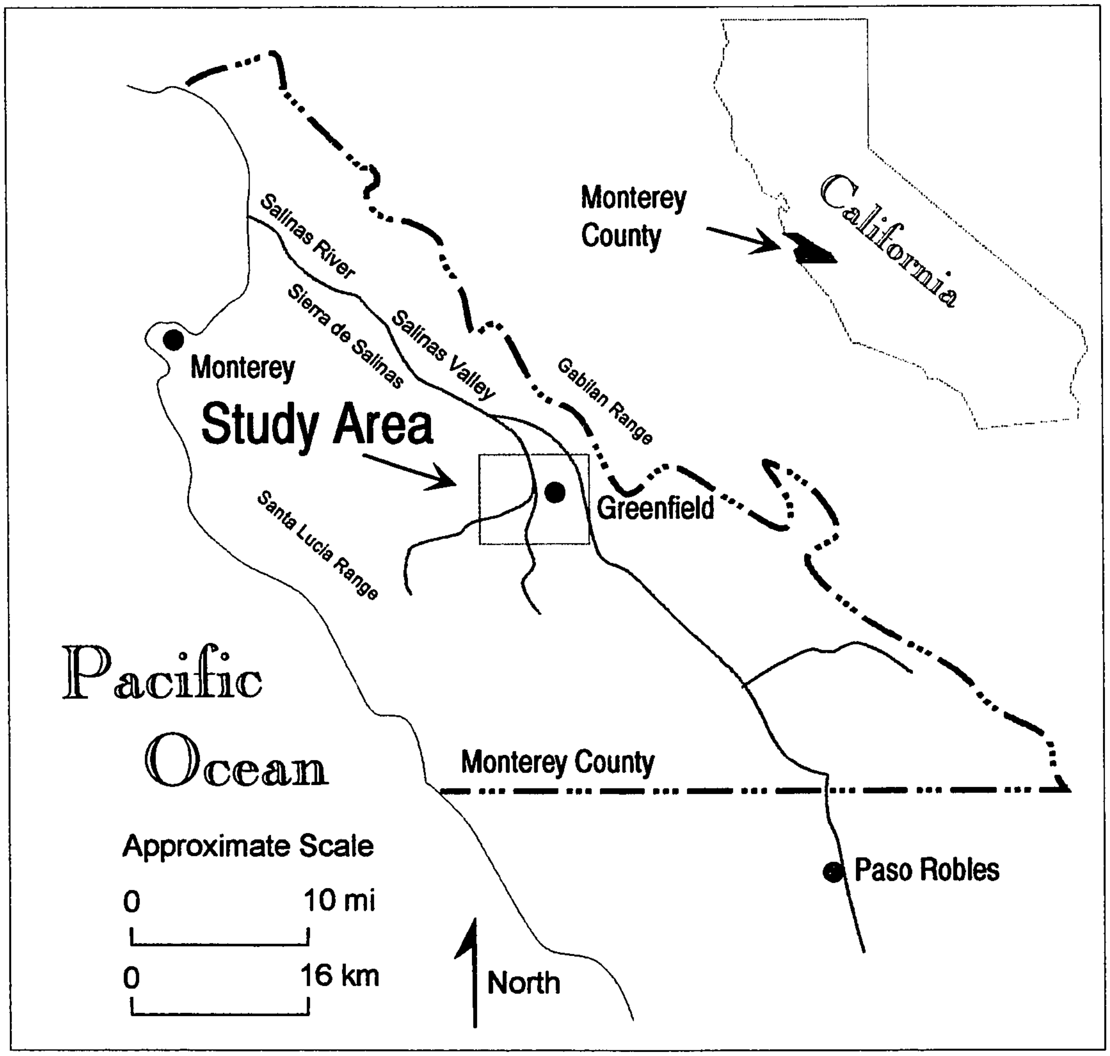


Figure 1. Index map. Study area (see Plate 1) includes portions of the Paraiso Springs and Greenfield quadrangles (modified after Durham, 1970).

29.39 cm (11.57 in) at King City and 32.61 cm (12.84 in) at Salinas airport for the years 1970 to 1981 (Boyle Engineering, 1986). Temperature in the basin varies from about 37.4°C. (100°F.) to below -17°C. (0°F.). Average temperature for the valley is 15.4°C. (60°F.), but often reaches 31.9°C. (90°F.) during the midday (Boyle Engineering, 1986).

Previous Investigations

Many geologic, geophysical, and hydrologic studies have been completed in the Salinas Valley. The first geologic observations regarding the Arroyo Seco area were reported by Whitney (1865). Since Whitney, many persons have worked in the Arroyo Seco area and their efforts are documented by Durham (1963, 1971, and 1974) and Dibblee (1976). Table 1 summarizes the work which was of importance to this study.

Of particular interest to the author were the discussions regarding the presence of the King City fault or other faults located along the western edge of the Salinas Valley. The King City fault was postulated largely on geomorphic evidence by early investigators of the Salinas Valley geology. The fault was believed to be buried along the western margin of the Salinas Valley beginning in Monterey Bay and extending southeastward intersecting the San Andreas fault in the Carrizo Plain (Dibblee, 1976). Although the idea of one large, continuous fault located along the western margin of the Salinas Valley is not currently supported by direct evidence, there is other evidence suggesting that several local faults occur along the western edge of the Salinas Valley (Dibblee, 1976).

Table 1. Selected listing of geologic information concerning the Arroyo Seco area.

Author	Date	Title	Importance to this survey
Gribi	1963	The Salinas basin oil province, in the guidebook, the geology of Salinas Valley and the San Andreas fault.	Evidence for right-lateral movement along the Reliz Fault is discussed. A new feature is described as the King City hinge rather than the King City fault.
Gribi	1967	Ancient shorelines of the Gabilan uplift, in guidebook, Gabilan Range and the adjacent San Andreas fault.	The northern extension of the Reliz fault along the eastern base Sierra de Salinas is discussed.
Durham	1970	Geology of the Sycamore Flat and Paraiso Springs quadrangles, Monterey County, California.	Report provides a geologic map and cross sections along with a detailed discussion of the geology of the Arroyo Seco area.
Dibblee	1974	Geologic maps of the Greenfield and Soledad 15-minute quadrangles.	Geological map provides additional geologic detail regarding the area.
Durham	1974	Geology of the Southern Salinas Valley Area, California.	Reports includes a geologic and gravity map covering the study area.
Dibblee	1976	The Rinconada and related faults in the southern Coast Ranges, California, and their tectonic significance.	The Reliz fault may have splays, similar to the Los Lobos thrust fault to the south. The Rinconada fault may have about 38 km (23.6 mi) of right slip movement.
Dibblee	1979	Cenozoic tectonics of the northeast flank of the Santa Lucia mountains from the Arroyo Seco to the Nacimiento river, California.	The report mentions a possible northern extension of the Los Lobos thrust approximately 17 km northwest of San Ardo.
State of California	1980	Division of Oil and Gas.	Provides listing of subsurface stratigraphy reported by operators.

GEOLOGIC SETTING

General

The rocks of central Salinas Valley consist predominantly of a blanket of Upper Cretaceous and Tertiary sedimentary rocks and overlie pre-Tertiary granite, metasediments, and older sedimentary rocks. Substantial geologic uplift is visible on the western side of the Salinas Valley adjacent to the Sierra de Salinas. Elevated river terraces and steep alluvial fans reflect the recent uplift of the mountain ranges and expose thick sections of sedimentary and granitic rocks. The Gabilan Range, sometimes referred to as the Gabilan Mesa, is located on the northeast side of the Salinas Valley and is lower in elevation than the Sierra de Salinas at most locations. The northwest-southeast trending Reliz fault is generally located along the eastern portions of the Santa Lucia Range and Sierra de Salinas and strikes nearly parallel to Salinas Valley (Figure 2).

Oil exploration of the Salinas Valley and Arroyo Seco area has been active since the early 1930's. Several oil exploratory wells were drilled into an anticlinal structure containing Miocene sedimentary rocks named the Monroe Swell (Figures 3a and 3b). The well records and logs from exploratory drilling have provided valuable geologic information used in this investigation.

Stratigraphy

The stratigraphic sequence in the Arroyo Seco area includes marine strata of middle and late Miocene and Pliocene age and non marine beds of

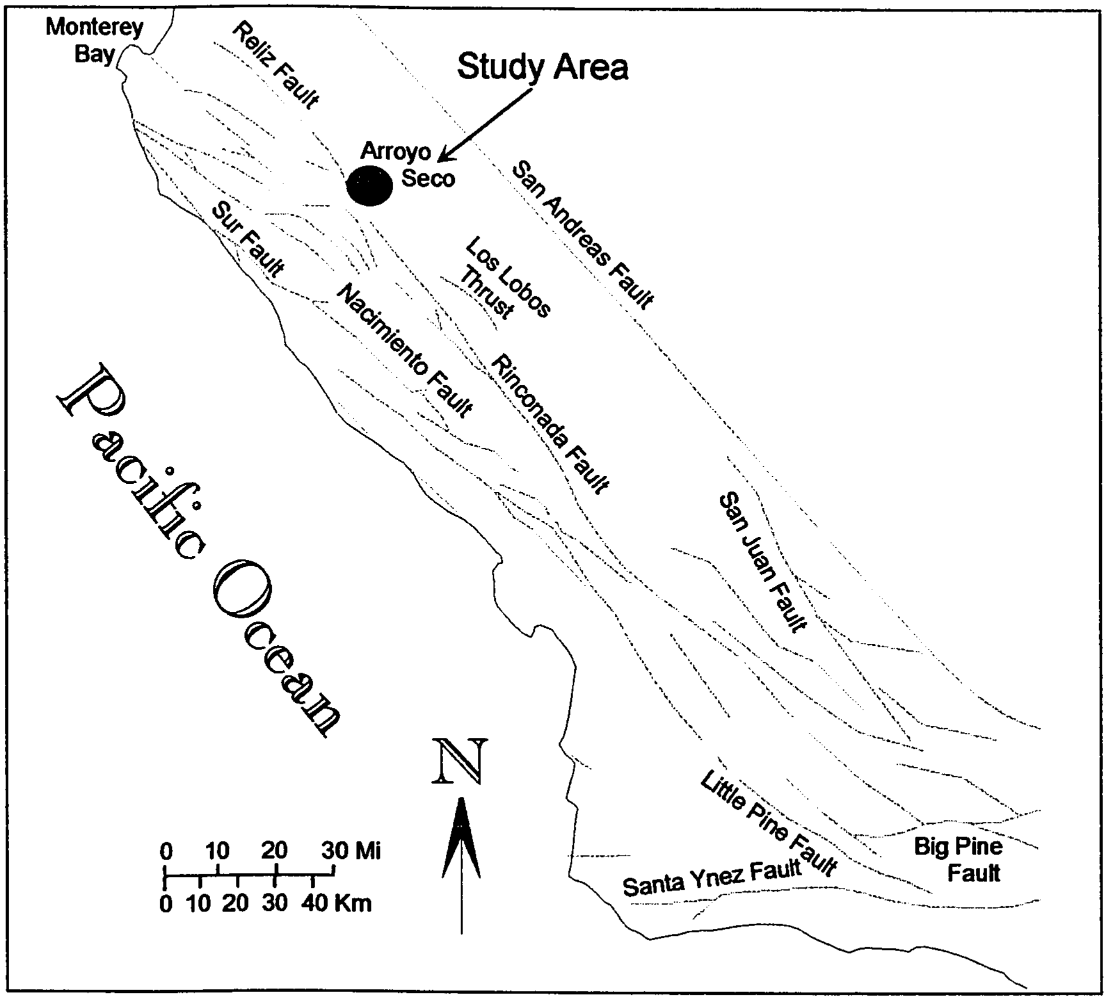


Figure 2. Generalized map of known faults in the central Coast Ranges (Modified after Dibblee, 1976).

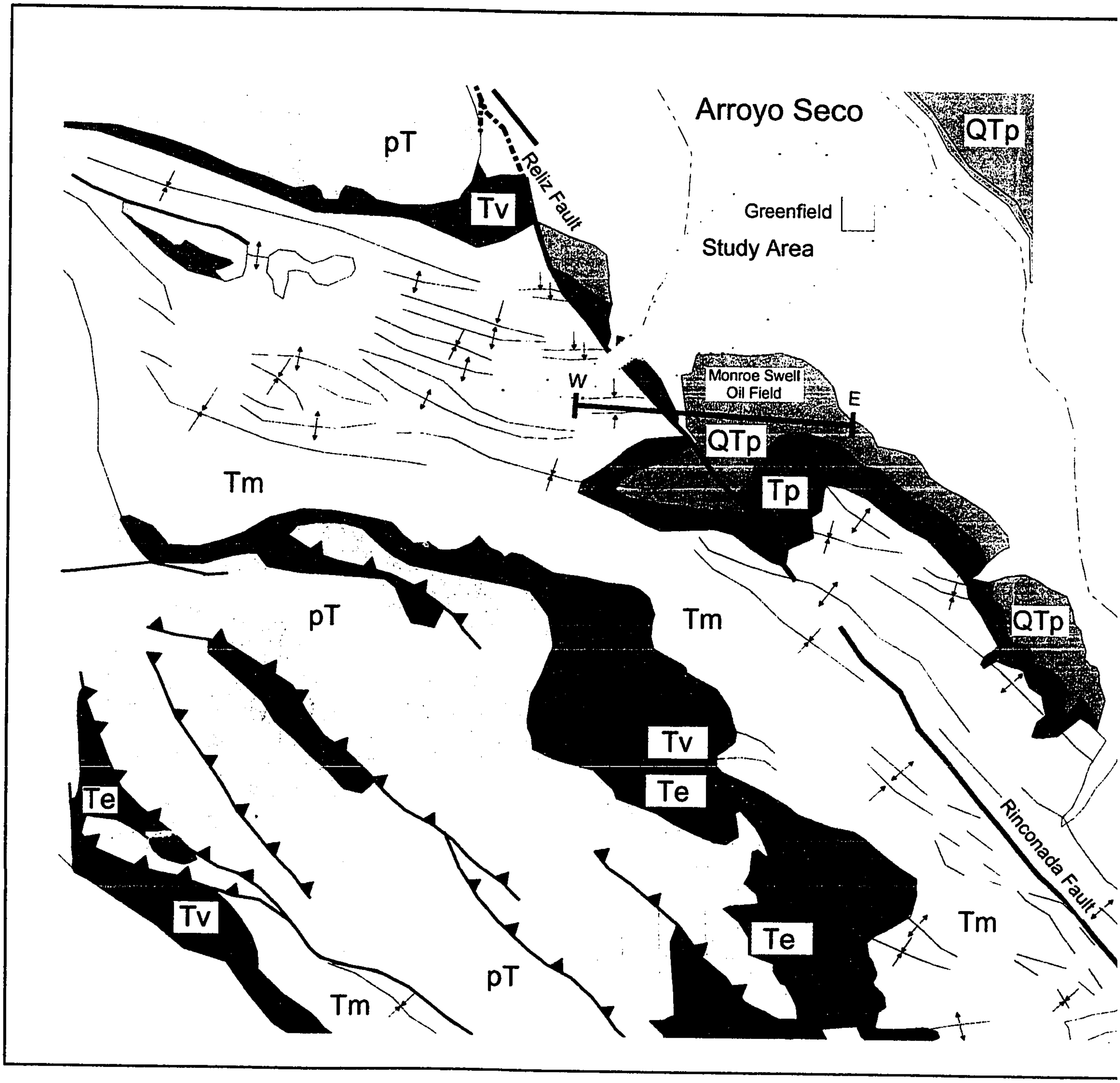
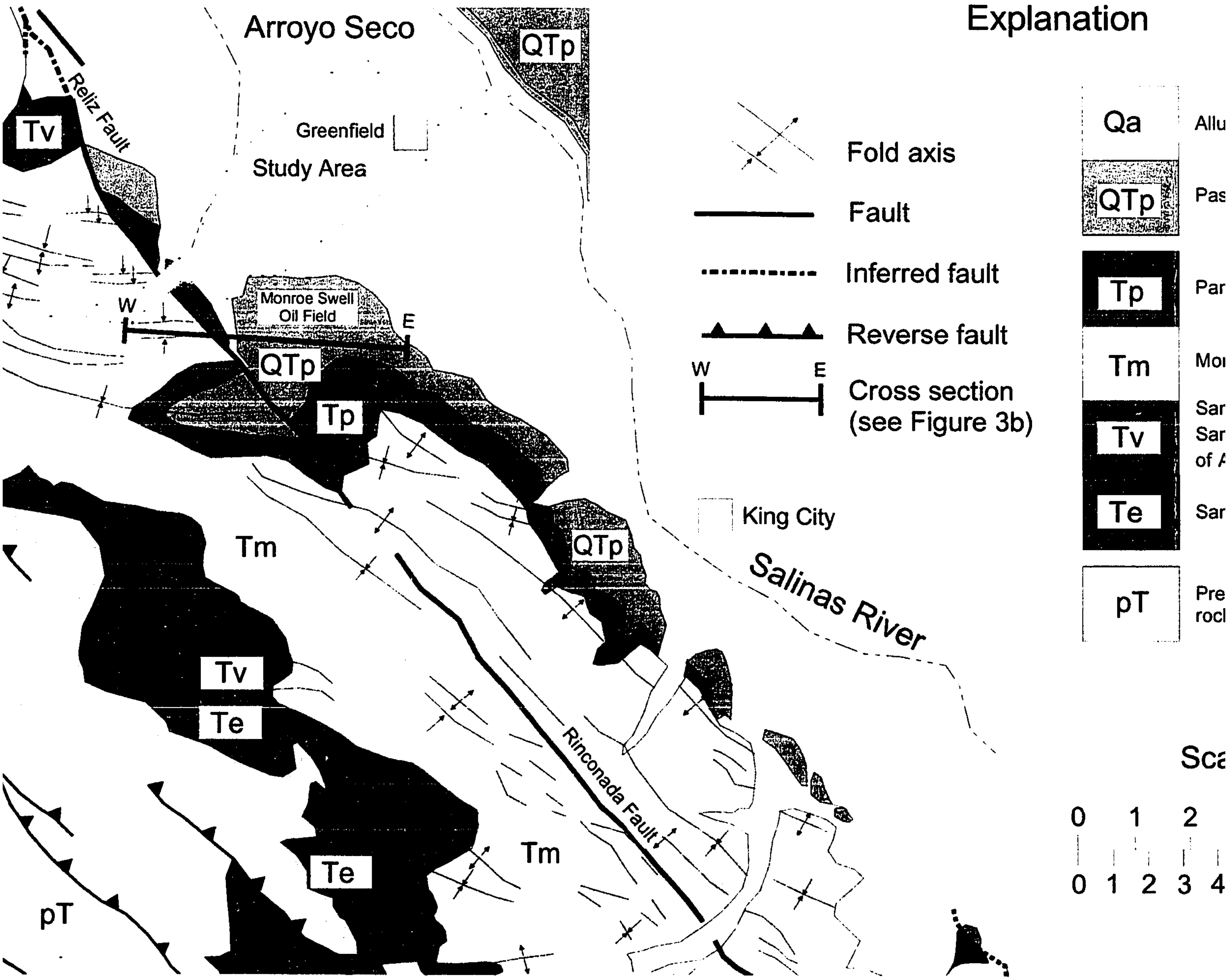
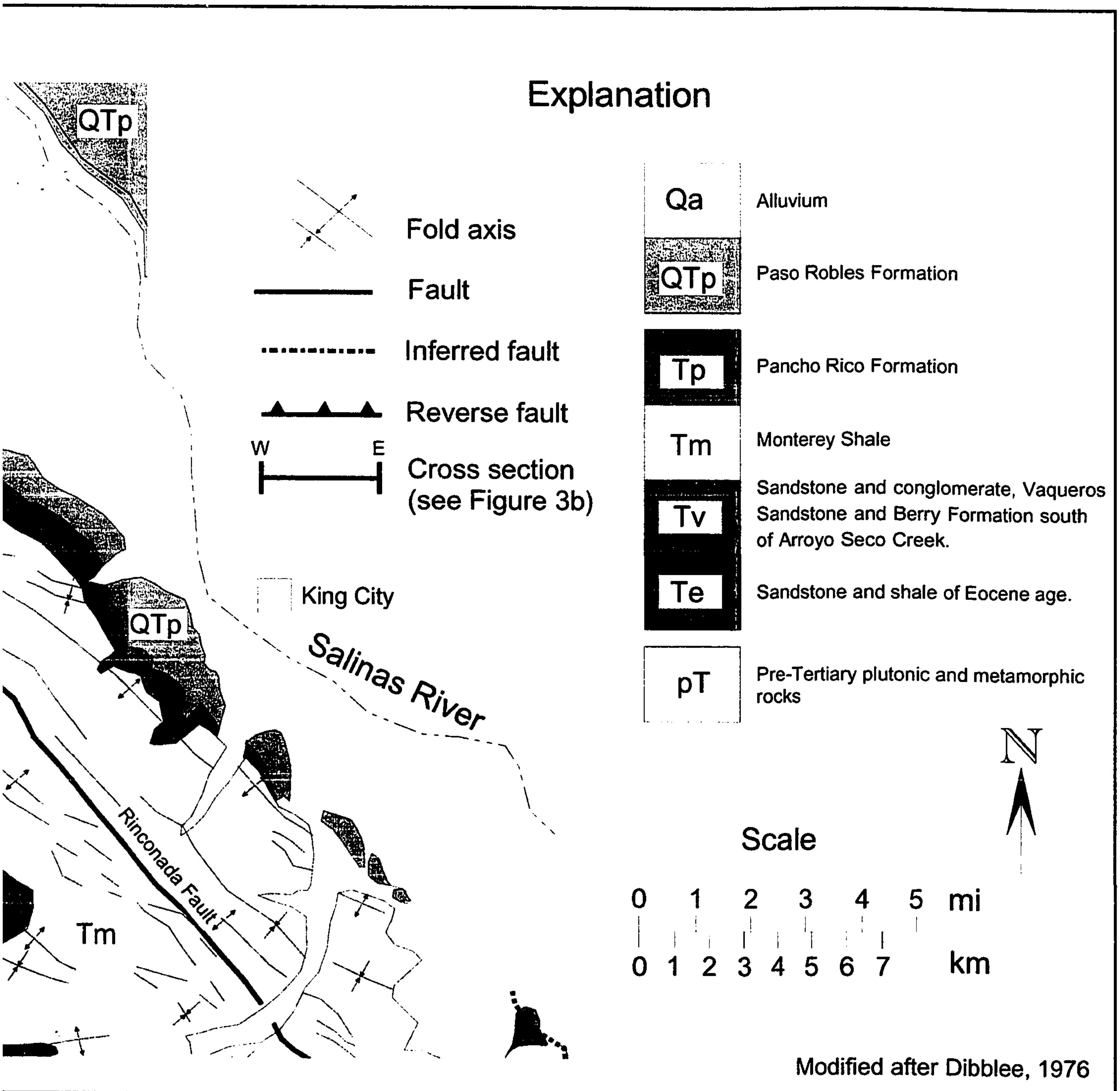


Figure 3a. Regional geologic setting near the Arroyo Seco area.



he Arroyo Seco area.


Explanation
Fold axis
Fault
Inferred fault
Reverse fault
W
E
Cross section
(see Figure 3b)
King City
Qa
Alluvium
QTp
Paso Robles Formation
Tp
Pancho Rico Formation
Tm
Monterey Shale
Tv
Sandstone and conglomerate, Vaqueros Sandstone and Berry Formation south of Arroyo Seco Creek.
Te
Sandstone and shale of Eocene age.
pT
Pre-Tertiary plutonic and metamorphic rocks
N
Scale
0 1 2 3 4 5 mi
0 1 2 3 4 5 6 7 km
QTp
QTp
Salinas River
Rinconada Fault
Tm
Modified after Dibblee, 1976

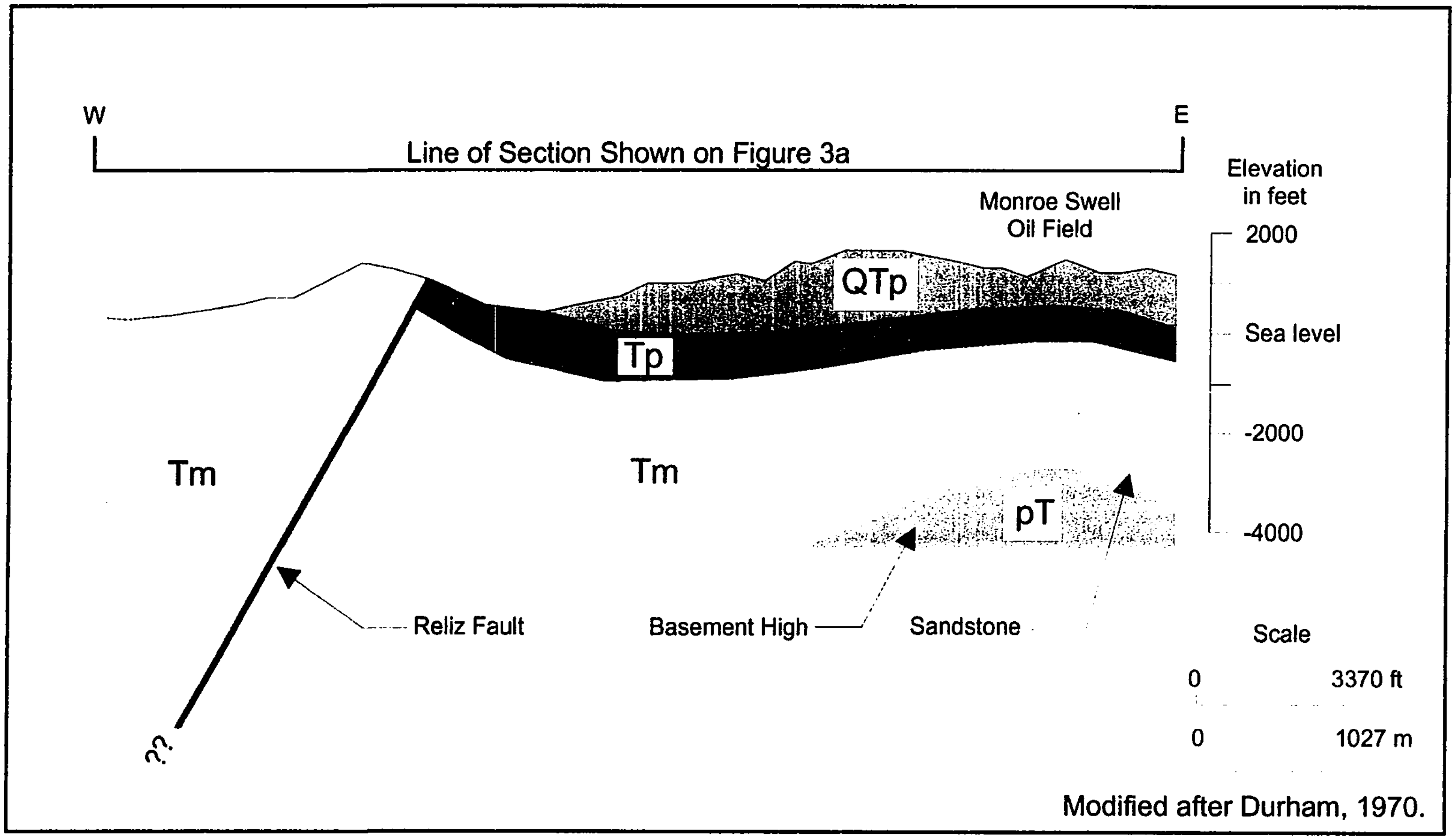


Figure 3b. East-West cross section of a portion of the Monroe Swell oil field.
For explanation of geologic units, refer to Figure 3a.

Pliocene and Pleistocene age that overlie a pre-Tertiary age "basement" complex. These strata constitute a conformable sequence consisting of four major units: The Tierra Redonda Formation, the Monterey Formation, the Pancho Rico Formation, and the Paso Robles Formation (Durham, 1970). These formations are unconformably overlain by a variety of younger Quaternary sediments. The distribution of mapped units with appropriate symbols is shown on Plate 1.

Basement Complex (pT)

The pre-Tertiary basement complex in the Arroyo Seco area consists of Cretaceous granitic and metamorphic rocks. The granitic rocks in the Santa Lucia Range were referred to as the Santa Lucia granite or granodiorite by Lawson (1893). The associated metamorphic rocks of the Salinian block were named the Sur Series by Trask (1926). The basement rocks located within the Gabilan Range were identified as quartz diorite or granodiorite (Ross, 1974). The basement rocks located in the study area are mainly Sur Series or granodiorite.

Tierra Redonda Formation (Tt)

The Tierra Redonda Formation is chiefly composed of a marine arkosic sandstone, conglomerate and mudstone. The sandstone unconformably overlies the basement near Paraiso Springs (Durham, 1970). The thickness is uncertain but is believed to be about 152 m (500 ft) thick near Paraiso Springs, northwest of the study area (Durham, 1970). The sandstone is middle Miocene age and is stratigraphically equivalent to the finer grained rocks in the Sandholdt Member of the Monterey Formation (Durham, 1974).

Monterey Formation (Tm)

The Monterey Formation conformably overlies the Tierra Redonda Formation. The Monterey Formation has two members present in the survey area: an older marine calcareous mudstone member referred to as the Sandholdt Member, and an overlying marine porcelaneous mudstone (Durham, 1970) also referred to as a siliceous shale (Dibblee, 1974). The stratigraphic thickness of the Monterey Formation is uncertain (due to geologic deformation) but the Sandholdt Member is estimated to be as great as 1,067 m (3,500 ft) in selected well logs (Durham, 1970). The overlying siliceous member of the Monterey Formation was estimated to be as great as 1,372 m (4,500 ft) by well logs (Durham, 1970).

Pancho Rico Formation (Tp)

The Pliocene Pancho Rico Formation is a marine arkosic sandstone and mudstone that comformably overlies the Monterey Formation. The sandstone is a massive, fine-grained rock which ranges from friable to well indurated in the Arroyo Seco area (Durham, 1970). Dibblee (1974) defines the Pancho Rico Formation (Tp) as a diatomaceous mudstone, shale, and fine-grained sandstone. On Dibblee's (1974) geological map, he separates Durham's (1970) fine-grained sandstone associated with the Pancho Rico Formation and defines it as the Unnamed Sandstone. The thickness of Durham's Pancho Rico Formation is estimated to be 259 m (850 ft) by well logs (Durham, 1970). For purposes of simplicity, the unnamed sandstone of Dibblee (1974) was combined and presented as Durham's (1970) Pancho Rico Formation in Plate 1.

Paso Robles Formation (QTp)

The Pliocene and Pleistocene Paso Robles Formation contains a pebble conglomerate with lesser amounts of sandstone and mudstone. The Paso Robles Formation conformably overlies the Pancho Rico Formation and unconformably underlies ancient alluvial sediments (Durham, 1970). The conglomerate is poorly sorted and mostly contains clasts from the Monterey Formation. The total thickness of the Paso Robles Formation is estimated to be greater than 427 m (1400 ft) and possibly up to 762 m (2,500 ft), as indicated by a well log analysis (Durham, 1970).

Alluvium and Recent Sediments

Older Alluvium covers the valley lowlands adjacent to stream terraces in the field area. The surface thickness is commonly 1.5 m to 3 m (5 to 10 ft) but has been observed up to 15 m (50 ft) in some gravel quarries (Durham, 1970). The old alluvium is often indistinguishable from the Pancho Rico Formation on electric well logs. The subsurface thickness is generally unknown because logs commonly do not show the first 152 m (500 ft) below the surface.

Structure

Folding

The Tertiary sediments, located west to southwest of Arroyo Seco, are tightly folded into a trend of locally anomalous east-west folds (Figure 3 and

Plate 1). On a large scale, the nearly east-west fold axes are between exposed portions of granitic and Sur Series rocks located north and southwest of the sediments. The eastern region of these folds is truncated by the Reliz fault and was interpreted by Gribi (1963) to be drag folds caused by right-lateral movement along the Reliz fault.

Reliz Fault

The Reliz fault segment is a major fault aligned with the Rinconada fault that trends along the base of the Santa Lucia Range and Sierra de Salinas. The Reliz fault segment is a 56 km (35 mi) portion of the larger 300 km (190 mi) Rinconada-Reliz fault system (Figure 2, Dibblee, 1976). The Rinconada-Reliz fault is believed to be a high-angle structure that strikes nearly parallel to the San Andreas fault, approximately 34 km (22 mi) to the northeast. The Reliz fault segment is visible in the Arroyo Seco area, especially near the Arroyo Seco Bridge, 8 km (5 mi) southwest of Greenfield. However, the fault is buried north of the Paraiso Springs area.

The northern portion of the Reliz fault, once referred to as a part of the King City fault, is now considered by Dibblee (1976) and others to be the northern extension of the system. Although the northern Reliz fault is concealed, there is strong geomorphic evidence for its existence such as the visibly disturbed alluvial fan material located 3 km (2 mi) northeast of Paraiso Springs (Dibblee, 1974 and 1976).

The Reliz fault near the Arroyo Seco area is considered to have a right-lateral component of movement suggested by the pattern of east-trending fold axes within the Tertiary strata on the southwest side of the fault (Gribi, 1963 and

Dibblee, 1976). Fairborn (1963) acquired a northeast-southwest gravity profile that was located at the base of the Sierra de Salinas (about 9 km or 6 mi southeast of Salinas) that indicated the presence of a fault with vertical displacement of 3,048 m (10,000 ft). The Reliz fault may be characterized by oblique slip with the zone generally north of Arroyo Seco showing evidence of thrust displacement. The zone south of Arroyo Seco shows evidence of strike-slip and a component of thrust motion. The fault was primarily active after the deposition of the Pancho Rico Formation, but is now considered inactive (Dibblee, 1976). Near the Arroyo Seco Bridge, the fault dips approximately 70° southwest as measured near the ground surface.

The King City Fault

The historic view of the King City fault existing from the southern portion of the Sierra de Salinas to Bradley is generally considered non-existent (Dibblee, 1976). Gribi (1963) referred to this segment as the King City hinge rather than the King City fault, suggesting that there is no evidence for a single fault showing essentially vertical movement along the western edge of the Salinas Valley. Gribi (1963) defines the King City hinge as the line which parallels several mappable faults and contains thick sections of incompetent shales which impinge against a competent basement buttress. In this zone, Gribi (1963) also indicates that faulting occurs when the folding has proceeded beyond the rupture point of the shales, such as observed along the Los Lobos thrust. Gribi (1963) suggested that the King City hinge may have originated as a basement fault.

Gribi (1963), Durham (1963, 1970, and 1974), Dibblee (1976), and others believe a largely inferred fault exists along the base of the Sierra de Salinas (just to the north of Arroyo Seco) and extends northwestward to Monterey Bay. This fault segment has been referred by Gribi (1967), Walrond, Thorup, Gribi, and Rodgers (1967), and Dibblee (1976) as the Reliz fault and not as the King City fault. Durham (1974) and Jennings (1973) refer to this same segment as the King City Fault and not as the Reliz fault.

GEOPHYSICAL SURVEY

General

A gravity survey was undertaken over an area of approximately 20.7 km^2 (8 mi^2) near Arroyo Seco. The gravity instrument used for all the field work was a Worden "Educator" gravity meter. The instrument has a sensitivity of 0.2 dial divisions per station. The field survey was performed over an eleven month period starting September 14, 1991, and ending August 8, 1992. The field work consisted of two phases, a preliminary evaluation phase and then a follow-up phase. Along with performing the geophysical survey, USGS earthquake epicenter data were obtained to aid in the geophysical and geologic interpretation of the Arroyo Seco area. The earthquake epicenter information is introduced and discussed in the Interpretation Section of this report.

Preliminary Evaluation Phase

During the preliminary evaluation phase, multiple individual stations and short profiles or "strings" were surveyed gravimetrically in an attempt to identify any possible anomalous areas. Gravity readings at a total of 285 stations were measured and evaluated for the preliminary phase of interpretation. Some of the stations were reoccupied to improve survey accuracy and to extend the lines where additional data were needed. Much of the preliminary phase data were used in the final results; excessively noisy or questionable data were not used for the preliminary interpretation.

As a result of the preliminary phase, two interesting zones were identified as significant anomalies. The first zone is located just east of the Reliz fault and extends just beyond the base station (see Plate 1, Detail Section, and Figure 4). The second zone is located east of the Reliz fault along Arroyo Seco Road (Plate 1, between stations 256 and 263, and Figure 4). The preliminary phase revealed that more work was needed to reduce elevation noise and decrease station distance in order to increase interpretation accuracy and confirm the presence of the anomalies. This was accomplished by completing a follow-up phase.

Follow-up Phase

The follow-up phase consisted of locating an additional 114 gravity stations, performing an elevation survey at each site, and decreasing station interval spacing to 30.4 m and 60.8 m (100 and 200 ft) within the anomalous zones. Following the elevation survey, gravity measurements were obtained at each station location--thereby increasing the spatial resolution of the gravity survey. By completing the elevation survey and increasing sampling density at the selected sites, the measurement noise was reduced and overall resolution improved. The preliminary phase and follow-up phases yielded a total of 399 station locations, of these, 288 are presented on Plate 1 and were used for the gravity interpretation (see Appendix A for basic gravity data).

Data Reduction

The final 288 gravity stations were occupied and corrected to a regional base station. The regional base is located just north of the Monroe Swell oil field and is noted on Plate 1. The regional base station was used as the reference for the drift, latitude, and elevation corrections. During the survey, the base was measured approximately 87 times, which includes the beginning of the field day, every hour thereafter, and at the end of each field day. The gravity corrections are as follows: drift correction, elevation correction (includes free air and Bouguer corrections), latitude correction, and terrain corrections. The gravity survey corrections were calculated using the spreadsheet programs Quattro Pro 4.0 and Excel 4.0.

Drift Correction

The drift correction was calculated by measuring the change of gravity at the base station each hour and calculating the drift per time value. These values were added or subtracted to all measurements each hour depending upon the drift, and then further corrected to 11:27 a.m., September 28, 1991, the first base station reading of the survey.

Elevation Correction

The elevation correction is a combined correction of free air and Bouguer effects. The value which was used was 0.2122 milligals/m (0.0647 milligals/ft). For the stations located topographically above base station elevation, the value was added to the raw data. For the stations topographically below the base station, the value was subtracted. The correction value of 0.2122 milligals/m (0.0647 milligals/ft) is based on an estimated sediment density of 2.0 gm/cc (Nettleton, 1940).

Terrain Correction

The terrain corrections for the survey were completed using the Hammer charts (Dobrin, 1988 and Hammer, 1939). Corrections were calculated for 17 locations in the survey area. A contour map was created and superimposed on the survey stations. Terrain correction values varied between 0.06 to 3.79 milligals depending on proximity to the mountains. The terrain corrections varied between these limits and were added to the appropriate value at the corresponding gravity station. The value of each correction was interpolated from the contour map.

Latitude Correction

Latitude corrections were made to correct the values of each gravity station to the regional base station latitude. This was accomplished by measuring a north-south coordinate of each station and calculating the distance north or south relative to the base station. The resulting gradient used for the correction was 0.000813 milligals/m (0.000248 milligals/ft). If a station was located north of the base, the correction was subtracted from the station value and if the station was located south of the base, the correction was added.

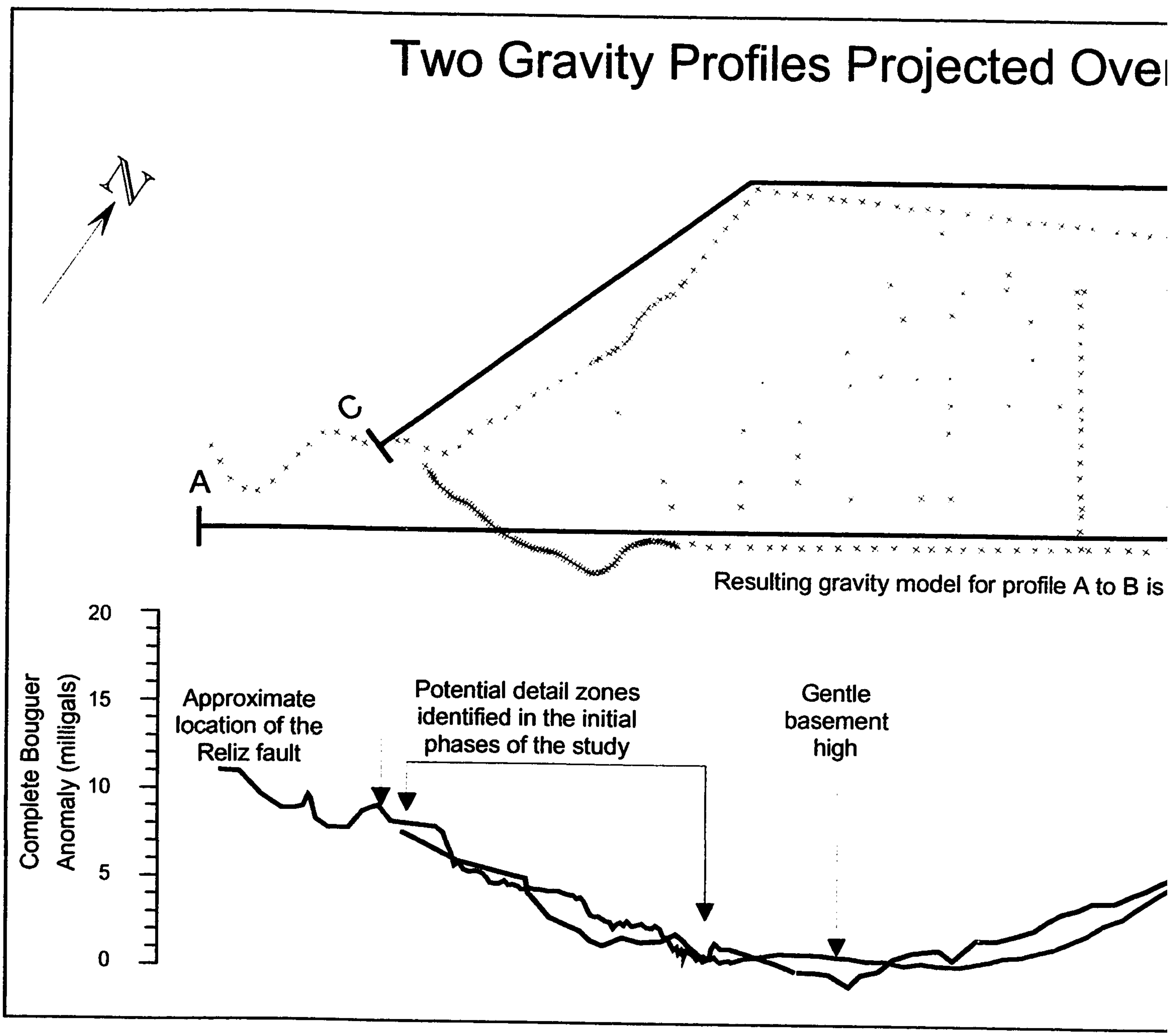
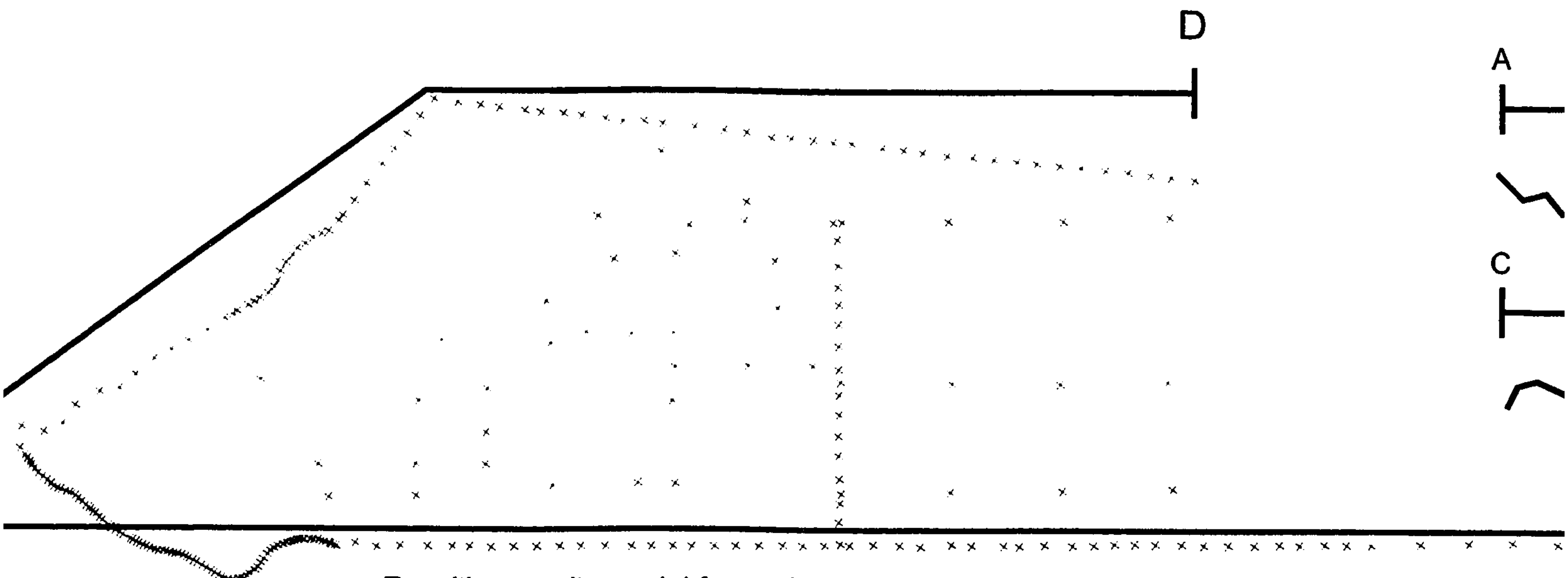
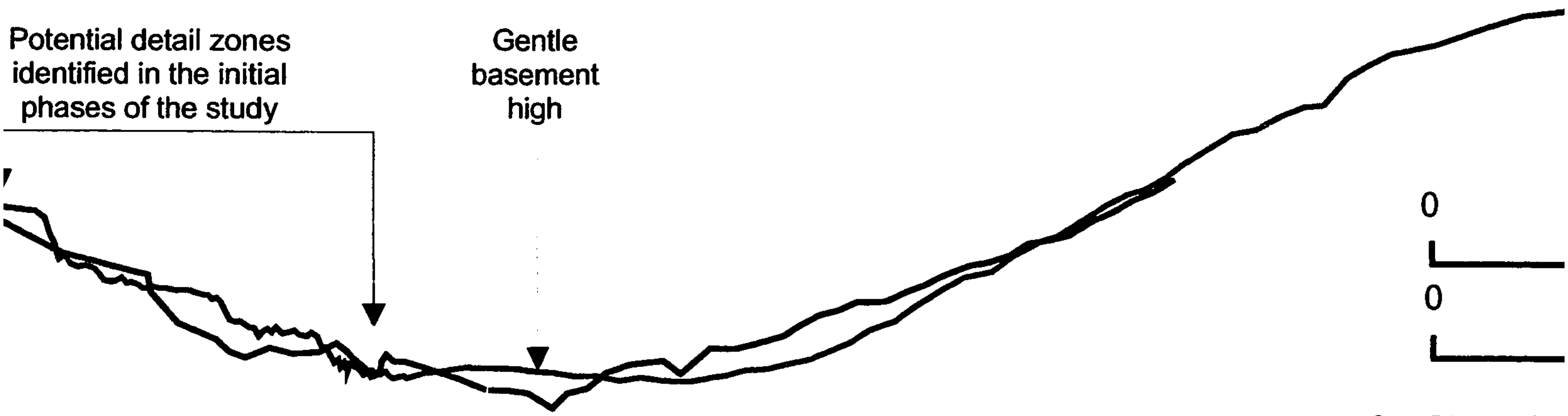


Figure 4. Two gravity profiles crossing portions of the Salinas Valley. Profiles are located on the s

'wo Gravity Profiles Projected Over Survey Stations

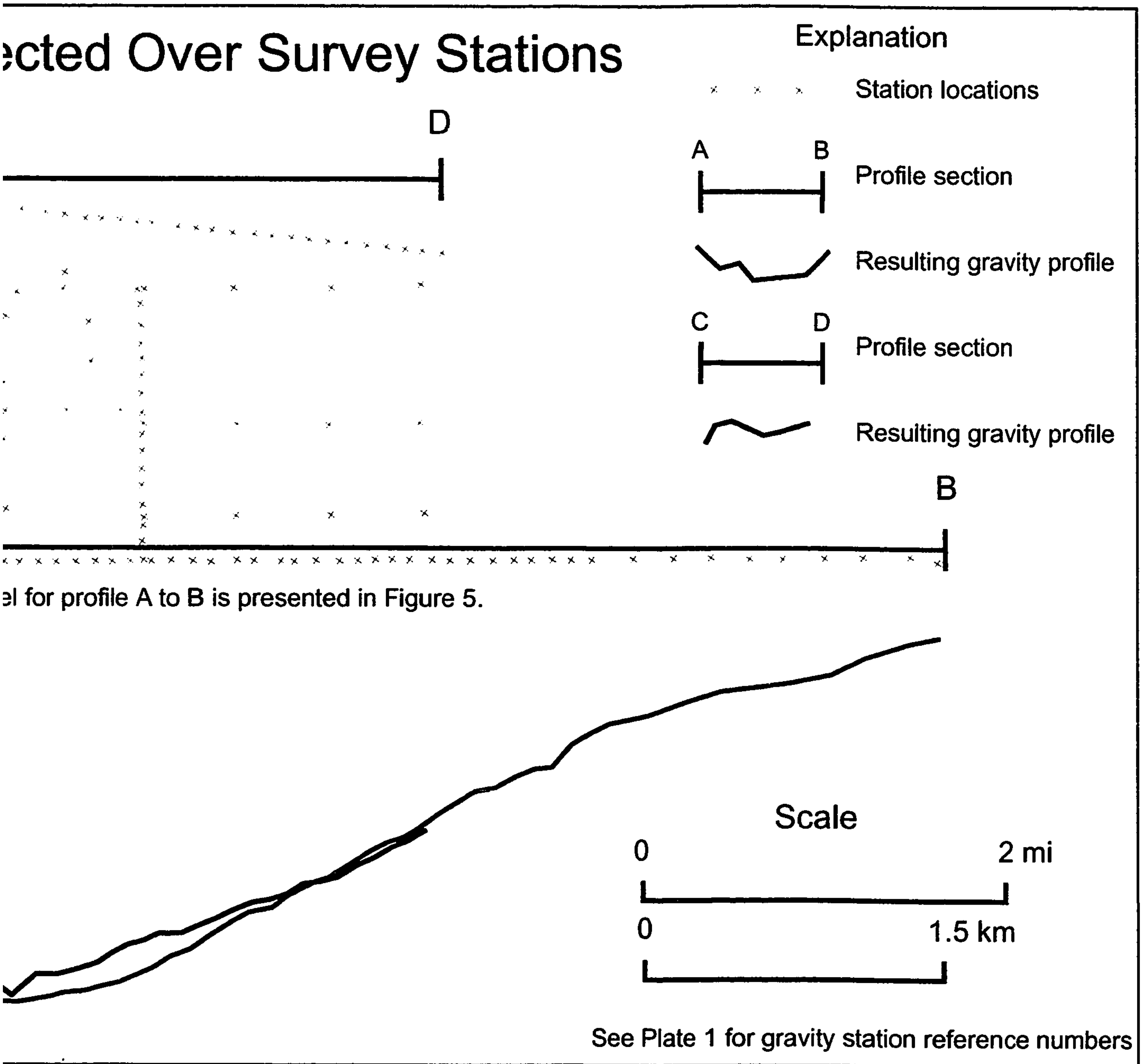


Resulting gravity model for profile A to B is presented in Figure 5.



See Plate 1 for

files crossing portions of the Salinas Valley. Profiles are located on the southern and northern portions of the survey ar



s are located on the southern and northern portions of the survey area.

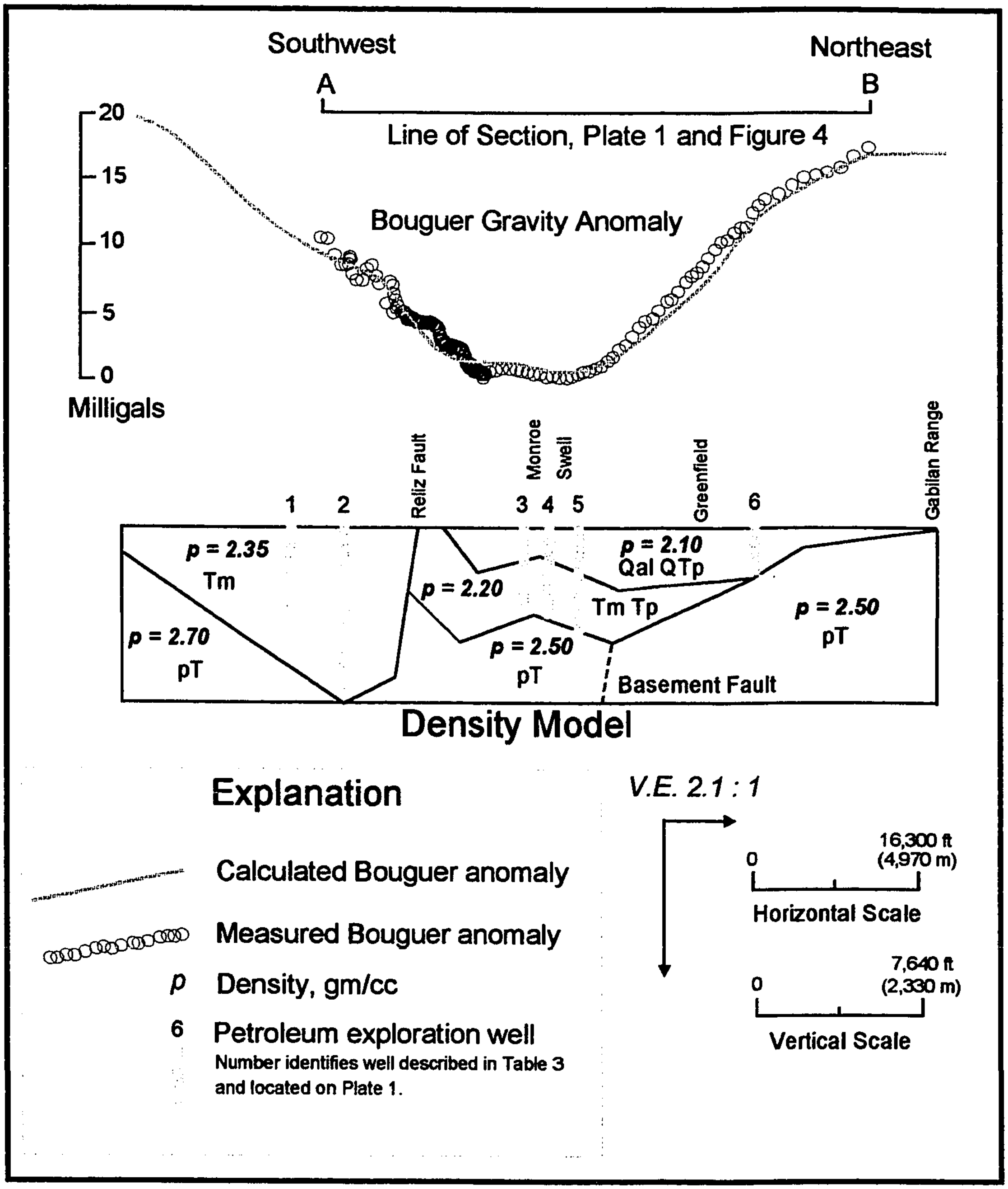


Figure 5. Gravity model of the Salinas Valley near the Arroyo Seco and Greenfield, Monterey County, California. Gravity datum is referenced to base station equals zero. Line of section corresponds to A-B profile indicated on Plate 1.

<u>Gravity model</u>

A southwest to northeast geologic model traversing the Salinas Valley and the Arroyo Seco area was calculated in order to interpret the observed anomalies. This model was constructed between station 150 on the southwest and station 242 on the northeast side of the field area (Plate 1, Figures 4 and 5). The profile line was suitable for a gravity based model for several reasons: the availability of stations traversing the Salinas Valley, the availability of subsurface information in exploration logs for model calibration, and the availability of geologic outcrops on each end of the profile line for correlation points. Some of the station locations did not fall onto the profile line and therefore were projected onto line A-B (Plate 1, Figures 4 and 5).

A two-dimensional model was constructed using the Gravcad computer program furnished by San Jose State University Department of Geology to more precisely interpret the anomalous zones. The personal computer program uses the Talwani algorithm to calculate the Bouguer anomaly over a polygon (Talwani, 1959). Talwani implemented the line integral method of Hubbert (1946). A model was then created using all pertinent information.

Rock densities of samples obtained from surface outcrops were measured in order to calculate the terrain corrections, and for gravity based models. Table 2 presents the values which have been used for other gravity models in similar environments. The density values measured from outcrop samples appear to be lower then the values used for identical and similar formations from other nearby gravity investigations. After calibrating the gravity model to known points as listed in Table 3, it was determined that the densities used by Burch (1970a and 1970b) in a similar geologic environment were much more consistent with the calibration. The resulting density values used for the gravity model are presented in Table 2.

The model boundaries were constrained by exploration wells, geologic outcrops, and the geologic cross sections constructed by Gribi (1963) and Durham (1970). Nine models were constructed using different combinations of layers representing different densities. The best-fitting models were simple models using few layers and densities similar to those contained in Burch (1970a and 1970b). The resulting calculated model for the profile A-B (Plate 1 and Figure 4) is presented as Figure 5. The geologic interpretation is discussed in the Interpretation Section of this report.

Table 2. Listing of rock densities (gm/cc) from various sources compared to the measured densities of similar formations in the Arroyo Seco area.

Author	**Burch-Durham**	**Burch-Dibblee**	**This study (sampled in outcrop)**	**This study (used in model)**
Location of samples	Paso Robles	Cholame	Arroyo Seco area	Arroyo Seco area
Surficial deposits (Qal)	2.2	1.4 to 2.0	Not measured	2.10
Paso Robles Fm. (QTp)	2.2	2.2	1.8	2.10
Pancho Rico Fm. (Tp)	2.3	2.2 to 2.3	2.1	2.20
Monterey Fm. (Tm)	2.3	2.3	1.7 and 1.9	2.20 and 2.35
Tierra Redonda Fm (Tt)	2.4	2.4	2.3	2.20
Paleocene/Cretaceous sedimentary rocks	2.5	2.5 to 2.6	Not present in surface outcrop	Not used in model
Basement rocks (pT)	2.67	2.6 to 2.9	2.5 to 2.7	2.5 and 2.7

Table 3. Listing of selected oil test wells used in gravity model interpretation.

Well on Plate No. 1	Notes	M D B & M T. R. Sec.	Operator	Well No. Year(s) Drilled	Total depth in feet	Well Stratigraphy (depth in feet)
1	2	19S 6E 20	Jones Oil Co.	"Harriman" 1 1923-25	4608	Monterey Shale 0 to 3000 Sandholdt Shale 3000 to 4608.
2	1	19S 6E 21	Humble Oil and Refining Co.	"C. N. Thorpe" 1 1950	7651	Monterey Shale 0 to 6730. Vaqueros Sandstone 6730 to 7651 (L. Miocene 7651).
3	2, 3	19S 6E 11	Santa Fe Drilling Co.	"Suter" 1 1962	4021	Base of "Santa Margarita Fm" 2690. Monterey Shale 2690 to 4021.
4	3,4,5	19S 6E 11	Phillips Petroleum	"Hansen" 1 1990	4350	Base of the Paso Robles 2690. Monterey Shale 2600+- to 4350.
5	2	19S 7E 18	Luard Corp.	"Marini" 1 1961	5010	Monterey Shale 2900-5010. Basement 5010
6	1,4	19S 7E 5	Standard Oil Co. of California	"Rianda" 1 1952	1511	Paso Robles 0 to 1492 Weathered Basement 1492

Notes:

1) Stratigraphy from California Department of Conservation: Division of Oil and Gas.
2) Stratigraphy from Durham, 1970
3) Interpretation of well log.
4) Location approximate.
5) Well location is referenced to Section 11 on the well log. The actual well site is shown within projected Section 12, 19S, 6E on Plate 1.

INTERPRETATION OF RESULTS

All of the geophysical data locations were placed on Plate 1 for interpretation and correlation. Plate 1 contains the following information: a modified geological map of the area after Durham (1970) and Dibblee (1974), contoured Bouguer values of this study area, a line of section A-B shown in Figures 4 and 5, and the earthquake epicenter locations. All of the gravity measurements presented are relative to a base station value of zero (See Appendix 1). Only earthquake epicenters occurring within the bounds of Plate 1 were plotted in an attempt to correlate between epicenter locations, gravity anomalies, and previously mapped faults (See Appendix 2).

Gravity Contour Map

A qualitative interpretation of the contoured gravity values indicates several features. The apparent northwest to southeast structural trend of the basement exists nearly parallel to the axis of the Salinas Valley. The granitic basement is exposed in several outcrops along the eastern side of the Salinas Valley which generally corresponds to the 19 milligal gravity contour. Gravity values decrease across the valley to the southwest, suggesting a southwest slope to the surface of the granitic basement. A transition in the gravity anomaly is located near the Arroyo Seco gorge where the gradient decreases and reverses direction to form a small high in the profile. The small gravity high is annotated as the "basement high" in Figures 3b and 4. This feature probably corresponds to the basement high associated with the Monroe Swell anticline (Figure 3b). Approximately three "steps" in the gravity profile A to B are indicated just northeast of the Reliz fault. The three "steps" align with the geologic contacts of Paso Robles Formation (QTp) to the east, alluvium in Reliz Canyon, and Pancho Rico Formation (Tp) to the west. On the southwest side of the Reliz fault, the gravity anomaly increases indicating the presence of higher density rocks in the subsurface.

The thickness of the sedimentary rocks on the southwest side of the Reliz fault is about 2,332 m (7,651 ft) and was observed in Well No. 2 on Plate 1, and noted in Table 3. Even though thick sections of low density sedimentary units of the Monterey Formation overlie the basement in this region, the increasing southwestward gravity gradient is relatively strong. The increasing value of the gravity anomaly (Figure 4) can be accounted for by several factors: (1) the presence of the higher density basement rock located on the southwest side of the Reliz fault; (2) the possibility of a shallow basement located outside of the survey line or in the third dimension, namely west and southwest of the field area; and (3) an increase in the density of the units in the Monterey Formation on the southwest side of the Reliz fault.

Gravity Model Interpretation

A gravity model was constructed along the Profile A to B to approximate the possible shape, depth, and density relationships of rock units located along the profile. The model was correlated with information from six oil exploration wells, geologic outcrops and fault locations, rock density measurements, and previous work (see Tables 2 and 3). An interpretation of the gravity profile A to B and model (Figure 5) generally agrees with the relations discussed in the previous section.

On examination of Figure 5, the density model indicates a southwest sloping basement beneath the Salinas Valley, away from the Gabilan Range. The basement "flattens" and forms an irregular surface observed as a small increase of the gravity anomaly in the center of profile A-B. The gravity anomaly was interpreted as a small basement high that formed the anticline within the overlying strata along the south of the field area (Figures 3b and 4). The basement structure was suggested by Gribi (1963) and Durham (1970) in their cross sections of the Salinas Valley. The gravity model shows the basement high may be related to a fault bounding the northeast side of the Monroe Swell.

The gravity model suggests the existence of higher density rocks located on the southwest side of the Reliz fault. The density measurements from outcrop samples located on either side of the fault, do not show any significant difference in density. The regional geological map (Figure 3) shows pre-Tertiary basement rocks are located in outcrop, about 4.8 km (3 mi) southwest of the Reliz fault. The surface of the pre-Tertiary rocks may slope gently east, toward the survey area, as shown in the model (Figure 5). The high gradient in the Bouguer anomaly observed southwest of the Reliz fault suggests that high density rocks may exist at shallow levels beneath the Monterey Formation.

Earthquake Epicenter Data

Earthquake epicenter information in the Arroyo Seco area was obtained to assist in the gravity modeling and subsequent geologic interpretation. The information was plotted on Plate 1 to determine if any significant lineations in the distribution of earthquakes indicates active faulting in the region. The data were obtained from the USGS for a 16 km (10 mi) radius centering on 36° 17.5' N and

121° 17.5' W and occurred between January 1, 1967 to June 11, 1993 . These events range in Richter magnitude between 0.5-2.4 and were located at depths of 4-13 km (2.4-8 mi).

Six of the earthquake epicenters form a semi-linear pattern along the western side of Salinas Valley (Figure 6). These earthquakes are as follows: No. 1, No. 2, No. 6, No. 10, No. 12, and No. 16 (Plate 1 and Appendix 2). The other earthquake epicenters are presented on Plate 1 but do not fit any significant pattern. The six epicenters which form this pattern also appear to generally align with faulting located in Sections 18, 19, and 20, T19S, R6E (Plate 1). To the south, the six earthquakes align with the mountain front along the west side of the Salinas Valley.

Discussion

Based on the results of this study, there is evidence to support the idea that a basement fault is located along the southwestern edge of the Salinas Valley in the vicinity of the Arroyo Seco gorge. Subsurface drilling data and the gravity model indicate that a basement high is located beneath, and just-north-of the Monroe Swell oil field. Faulting of the basement could cause the sediments to arch over an upthrown basement block as illustrated in Figure 3b. Evidence for this basement high was derived from gravity modeling along profile A-B (Figures 4 and 5). The basement fault is located along the gravity low, just northeast of the basement high. The basement fault appears to project along the long axis of the Salinas Valley and may project along a similar gravity low shown on gravity profile C to D (Figure 4). The location of the inferred basement fault is noted on Figure 6.

Six earthquake epicenters form a linear trace and are shown on Figure 6. The trace of the epicenters lies along the southward projection of a fault surface shown on Plate 1 and Figure 6. The six earthquake epicenters also lie along the inferred basement fault indicated by the gravity survey. The presence of the earthquake activity suggest that the basement fault is active, resulting in the folding of overlying strata.

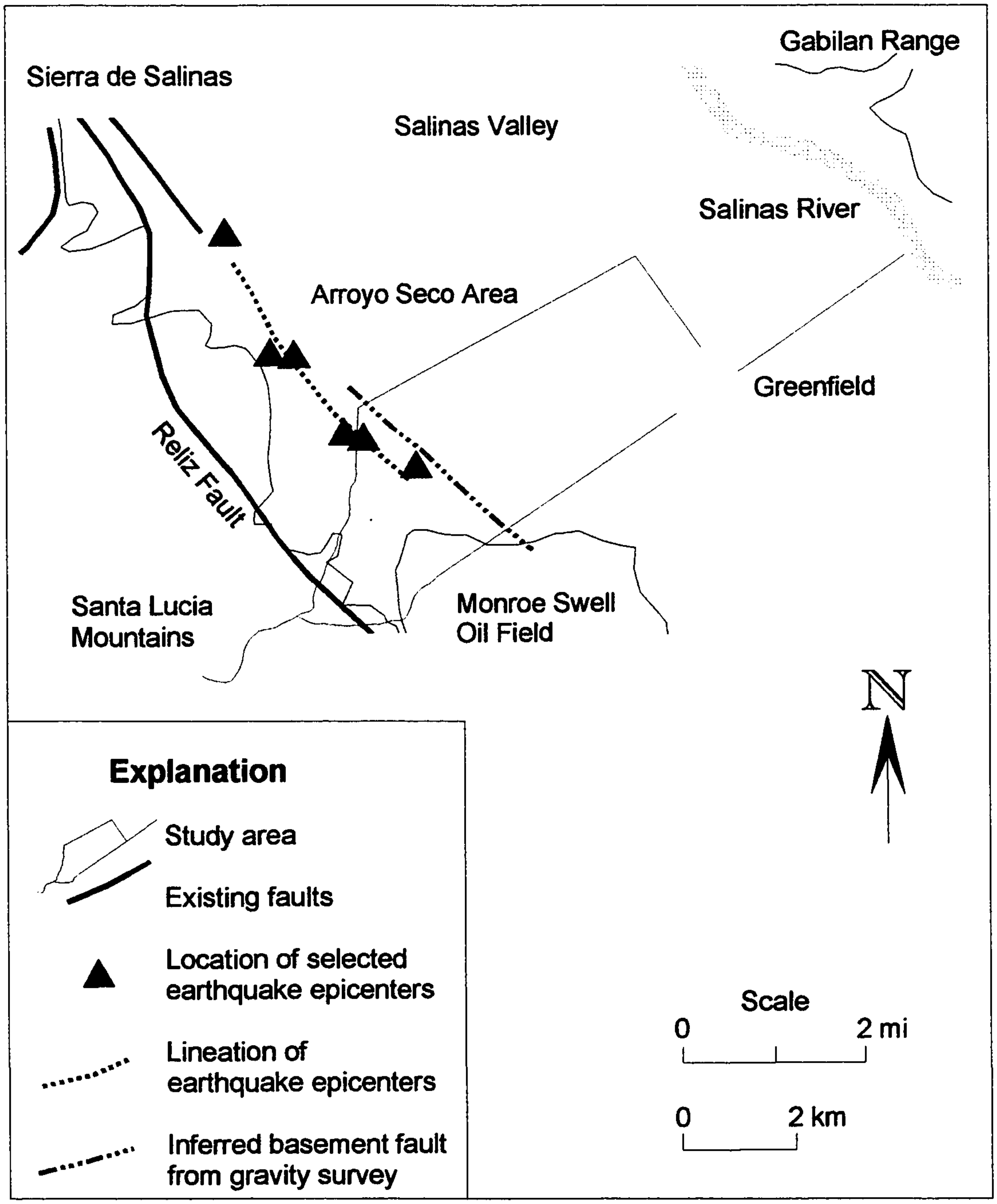


Figure 6. Map showing the approximate locations of the earthquake lineations and the inferred basement fault.

CONCLUSIONS

Several conclusions are drawn concerning the nature of the subsurface geology based upon gravity modeling and the location of recent earthquake epicenters within the investigated site. This survey provides evidence that a fault which offsets granitic basement exists along the western edge of the Salinas Valley in the Arroyo Seco area. This hypothesis was suggested by Gribi (1963), Dibblee (1976), and other early investigators of the area. Uplift of the basement rocks occuring along the fault disclosed by the gravity survey has formed a broad anticline in the overlying sediments. This structural feature is known to exist in the Monroe Swell oil field located just to the south of the study area. The basement fault also lies near recent earthquake epicenters suggesting that it is active. The pattern of epicenters is located along a southern extension of a surface fault mapped by Dibblee (1974) and nearly coincides with the basement fault indicated by the gravity survey. This study provides additional information on potential seismogenic structures along western Salinas Valley.

The results from the study have provided new information that may assist geologists and planners to identify areas of potential faulting. This information may be helpful in the planning of ground water management, oil exploration, and land use issues in the Arroyo Seco area.

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Appendix A

Basic Gravity Data

Station	Observed gravity after drift correction (milligals)	Elevation (feet)	Elevation correction (milligals)	Latitude correction (milligals)	Terrain correction (milligals)	Complete Bouguer anomaly relative to base = 0 (milligals)
Base	246.09	408.0	0.00	0.00	1.13	0.00
21	247.77	402.0	-0.39	-0.34	1.04	0.86
22	247.39	405.0	-0.19	-0.22	1.05	0.80
23	249.52	385.0	-1.49	-0.69	0.82	0.94
24	250.16	375.0	-2.14	-0.94	0.65	0.51
25	250.65	374.0	-2.20	-1.09	0.62	0.76
55	257.02	376.0	-2.07	-1.32	0.57	0.70
56	256.37	381.0	-1.74	-1.01	0.75	0.86
57	255.59	382.5	-1.65	-0.54	0.85	0.75
58	256.09	365.0	-2.78	-1.08	0.53	-0.75
59	258.60	349.7	-3.78	-1.39	0.40	0.33
60	259.58	345.0	-4.07	-1.52	0.35	0.83
61	257.97	367.0	-2.65	-1.76	0.42	0.47
62	258.00	351.0	-3.69	-1.95	0.35	-0.79
63	259.69	351.5	-3.66	-2.09	0.30	0.74
64	260.06	346.0	-4.02	-2.25	0.25	0.55

Basic Gravity Data

Station	Observed gravity after drift correction (milligals)	Elevation (feet)	Elevation correction (milligals)	Latitude correction (milligals)	Terrain correction (milligals)	Complete Bouguer anomaly relative to base = 0 (milligals)
65	260.43	335.0	-4.73	-2.63	0.24	-0.19
66	260.39	348.0	-3.88	-2.09	0.25	1.17
67	260.37	346.0	-4.01	-1.91	0.25	1.20
68	260.98	339.0	-4.46	-2.35	0.19	0.86
69	263.59	327.5	-5.21	-2.58	0.16	2.46
70	263.42	329.0	-5.11	-2.73	0.17	2.25
71	263.32	327.0	-5.24	-2.95	0.17	1.79
72	263.36	324.0	-5.43	-3.03	0.19	1.58
73	266.64	278.0	-8.41	-3.14	0.19	1.78
74	266.48	271.0	-8.86	-3.08	0.26	1.29
75	263.96	278.0	-8.41	-2.55	0.29	-0.21
76	264.48	288.0	-7.76	-2.40	0.28	1.10
77	265.31	278.0	-8.41	-2.82	0.22	0.79
78	261.32	300.0	-6.99	-1.95	0.40	-0.72
79	259.59	330.0	-5.04	-1.38	0.64	0.30
80	258.70	335.0	-4.73	-0.56	1.11	1.03
95	279.72	304.0	-6.73	-3.75	0.09	4.79

Basic Gravity Data

Station	Observed gravity after drift correction (milligals)	Elevation (feet)	Elevation correction (milligals)	Latitude correction (milligals)	Terrain correction (milligals)	Complete Bouguer anomaly relative to base = 0 (milligals)
96	282.86	290.0	-7.64	-4.15	0.07	6.59
97	286.48	274.0	-8.67	-4.55	0.05	8.77
98	274.78	324.0	-5.43	-2.60	0.14	2.34
99	278.30	308.0	-6.47	-2.98	0.09	4.39
100	281.67	296.0	-7.24	-3.35	0.07	6.60
101	285.25	286.0	-7.89	-3.74	0.05	9.11
102	274.93	318.0	-5.82	-2.06	0.17	2.67
103	278.74	303.0	-6.80	-2.44	0.11	5.06
104	281.90	298.0	-7.11	-2.84	0.07	7.47
105	285.76	286.0	-7.90	-3.24	0.05	10.12
136	274.64	455.0	3.04	0.61	2.04	8.12
137	274.88	463.0	3.56	0.70	2.07	9.01
138	273.94	470.0	4.01	0.77	2.14	8.66
139	272.57	476.0	4.40	0.79	2.17	7.72
140	271.80	486.0	5.05	0.83	2.24	7.71
141	271.67	494.0	5.56	0.89	2.27	8.19
142	272.14	503.0	6.15	1.02	2.22	9.33

Basic Gravity Data

Station	Observed gravity after drift correction (milligals)	Elevation (feet)	Elevation correction (milligals)	Latitude correction (milligals)	Terrain correction (milligals)	Complete Bouguer anomaly relative to base = 0 (milligals)
143	271.84	510.0	6.60	1.13	2.17	9.53
144	271.03	518.0	7.12	1.27	2.10	9.32
145	270.22	523.0	7.44	1.41	2.04	8.90
146	269.64	529.0	7.83	1.54	2.00	8.80
147	269.16	535.0	8.21	1.58	2.03	8.78
148	269.61	539.0	8.47	1.58	2.11	9.57
149	270.26	548.0	9.05	1.53	2.23	10.87
150	269.72	556.0	9.58	1.47	2.37	10.93
155	278.92	366.0	-2.72	-2.60	0.46	-0.21
156	279.38	360.0	-3.11	-2.67	0.43	-0.23
157	280.18	347.0	-3.94	-2.72	0.40	-0.35
158	280.53	333.0	-4.86	-2.80	0.37	-1.03
159	282.11	320.0	-5.69	-2.85	0.36	-0.34
160	284.98	280.0	-8.28	-2.92	0.34	-0.15
161	285.88	278.0	-8.41	-2.98	0.33	0.55
162	286.54	275.0	-8.60	-3.05	0.29	0.91
163	286.85	273.0	-8.73	-3.10	0.27	1.02

Basic Gravity Data

Station	Observed gravity after drift correction (milligals)	Elevation (feet)	Elevation correction (milligals)	Latitude correction (milligals)	Terrain correction (milligals)	Complete Bouguer anomaly relative to base = 0 (milligals)
164	287.22	270.0	-8.93	-3.17	0.26	1.11
165	287.34	260.0	-9.58	-3.22	0.25	0.52
166	288.16	267.0	-9.12	-3.32	0.22	1.68
167	288.46	264.0	-9.32	-3.40	0.22	1.69
168	289.05	260.0	-9.57	-3.47	0.20	1.94
169	289.50	260.0	-9.58	-3.53	0.18	2.30
170	289.31	272.0	-8.80	-3.60	0.17	2.81
171	289.80	273.0	-8.73	-3.67	0.16	3.29
172	290.49	267.0	-9.12	-3.73	0.15	3.52
173	290.79	269.0	-9.00	-3.79	0.14	3.88
174	288.73	303.0	-6.79	-3.88	0.12	3.91
175	289.27	302.0	-6.86	-3.94	0.12	4.32
176	289.77	300.0	-6.99	-3.99	0.11	4.63
177	290.51	298.0	-7.12	-4.06	0.10	5.16
178	291.05	297.0	-7.18	-4.14	0.09	5.55
179	291.47	294.0	-7.38	-4.20	0.08	5.70
180	291.99	292.0	-7.51	-4.28	0.08	6.02

Basic Gravity Data

Station	Observed gravity after drift correction (milligals)	Elevation (feet)	Elevation correction (milligals)	Latitude correction (milligals)	Terrain correction (milligals)	Complete Bouguer anomaly relative to base = 0 (milligals)
181	292.71	290.0	-7.64	-4.34	0.07	6.54
182	292.98	289.0	-7.70	-4.41	0.07	6.68
183	293.50	286.0	-7.90	-4.47	0.06	6.92
184	294.41	283.0	-8.09	-4.55	0.06	7.57
185	295.17	279.0	-8.35	-4.62	0.05	7.99
186	295.94	277.0	-8.47	-4.68	0.05	8.56
187	296.56	274.0	-8.67	-4.75	0.04	8.91
188	297.38	271.0	-8.87	-4.81	0.05	9.48
189	279.37	404.0	-0.26	-0.10	1.05	0.50
190	280.01	398.0	-0.65	-0.15	1.00	0.64
191	280.70	392.0	-1.04	-0.24	0.95	0.80
192	281.24	386.0	-1.43	-0.33	0.86	0.77
193	281.68	381.0	-1.75	-0.42	0.80	0.74
194	281.87	378.0	-1.94	-0.49	0.75	0.63
195	282.17	374.0	-2.20	-0.56	0.73	0.57
196	282.32	371.0	-2.40	-0.65	0.71	0.42
197	282.71	367.0	-2.65	-0.73	0.65	0.41

Basic Gravity Data

Station	Observed gravity after drift correction (milligals)	Elevation (feet)	Elevation correction (milligals)	Latitude correction (milligals)	Terrain correction (milligals)	Complete Bouguer anomaly relative to base = 0 (milligals)
198	282.95	362.0	-2.97	-0.81	0.60	0.20
199	283.40	359.0	-3.17	-0.89	0.55	0.32
200	283.54	357.0	-3.30	-0.97	0.50	0.20
201	284.02	351.0	-3.69	-1.06	0.46	0.16
202	284.44	348.0	-3.88	-1.13	0.44	0.29
203	284.86	346.0	-4.02	-1.21	0.40	0.47
204	285.42	342.0	-4.27	-1.27	0.37	0.68
205	285.88	338.0	-4.53	-1.35	0.35	0.77
206	286.34	336.0	-4.66	-1.43	0.32	1.00
207	286.95	332.0	-4.92	-1.51	0.28	1.23
208	287.66	329.0	-5.12	-1.60	0.26	1.64
209	288.42	324.0	-5.44	-1.67	0.25	2.00
210	289.28	322.0	-5.56	-1.75	0.22	2.62
211	289.98	319.0	-5.76	-1.83	0.20	3.02
212	291.21	313.0	-6.15	-1.92	0.18	3.75
213	292.31	309.0	-6.40	-2.01	0.16	4.49
214	293.09	306.0	-6.60	-2.07	0.15	5.00

Basic Gravity Data

Station	Observed gravity after drift correction (milligals)	Elevation (feet)	Elevation correction (milligals)	Latitude correction (milligals)	Terrain correction (milligals)	Complete Bouguer anomaly relative to base = 0 (milligals)
215	293.94	299.0	-7.05	-2.19	0.12	5.25
216	294.81	297.0	-7.19	-2.26	0.11	5.91
217	295.92	293.0	-7.44	-2.37	0.10	6.64
218	296.39	290.0	-7.63	-2.42	0.09	6.86
219	297.27	288.0	-7.77	-2.52	0.08	7.50
220	298.18	288.0	-7.77	-2.61	0.07	8.30
221	298.66	289.0	-7.70	-2.69	0.07	8.77
222	298.95	290.0	-7.64	-2.77	0.07	9.04
223	299.67	288.0	-7.77	-2.84	0.06	9.55
224	300.54	286.0	-7.89	-2.91	0.06	10.23
225	301.49	284.0	-8.02	-3.00	0.05	10.95
226	302.30	282.0	-8.15	-3.07	0.05	11.55
227	302.90	277.0	-8.48	-3.16	0.05	11.75
228	303.80	274.0	-8.67	-3.25	0.05	12.37
229	304.55	270.0	-8.93	-3.34	0.06	12.77
230	305.36	260.0	-9.58	-3.41	0.06	12.86
231	306.64	260.0	-9.57	-3.50	0.07	14.07

Basic Gravity Data

Station	Observed gravity after drift correction (milligals)	Elevation (feet)	Elevation correction (milligals)	Latitude correction (milligals)	Terrain correction (milligals)	Complete Bouguer anomaly relative to base = 0 (milligals)
232	307.63	255.0	-9.89	-3.58	0.08	14.67
233	308.82	246.0	-10.48	-3.67	0.09	15.20
234	309.77	241.0	-10.80	-3.85	0.09	15.64
235	310.48	243.0	-10.67	-4.03	0.17	16.38
236	311.16	243.0	-10.68	-4.19	0.25	16.97
237	311.65	240.0	-10.87	-4.34	0.33	17.20
238	311.95	240.0	-10.87	-4.48	0.40	17.43
239	313.32	227.0	-11.71	-4.66	0.48	17.86
240	314.82	220.0	-12.17	-4.82	0.55	18.81
241	315.98	215.0	-12.48	-5.03	0.65	19.55
242	314.74	240.0	-10.87	-5.11	0.70	19.89
244	284.29	450.0	2.72	0.57	2.00	7.55
245	283.81	435.0	1.75	0.52	1.90	5.96
246	283.57	430.0	1.42	0.47	1.81	5.25
247	283.10	435.0	1.75	0.37	1.77	4.96
248	282.19	440.0	2.07	0.23	1.77	4.23
249	280.92	440.0	2.07	0.08	1.72	2.76

Basic Gravity Data

Station	Observed gravity after drift correction (milligals)	Elevation (feet)	Elevation correction (milligals)	Latitude correction (milligals)	Terrain correction (milligals)	Complete Bouguer anomaly relative to base = 0 (milligals)
250	279.71	450.0	2.72	-0.01	1.64	2.04
251	279.63	445.0	2.39	-0.14	1.60	1.46
252	279.89	440.0	2.07	-0.28	1.54	1.20
253	280.54	440.0	2.08	-0.39	1.45	1.65
254	280.46	440.0	2.07	-0.49	1.38	1.40
255	280.72	440.0	2.07	-0.61	1.30	1.46
256	281.22	440.0	2.07	-0.71	1.25	1.81
257	280.93	435.0	1.75	-0.82	1.20	1.03
258	281.04	428.0	1.29	-0.95	1.15	0.51
259	281.49	424.0	1.03	-1.09	1.10	0.51
260	282.48	418.0	0.64	-1.23	1.10	0.97
261	283.08	414.0	0.39	-1.36	1.06	1.15
262	283.44	410.0	0.13	-1.49	1.00	1.05
263	283.77	406.0	-0.13	-1.64	0.94	0.91
264	284.60	401.0	-0.46	-1.75	0.90	1.27
265	284.79	398.0	-0.65	-1.88	0.85	1.09
266	284.81	393.0	-0.97	-2.02	0.80	0.59

Basic Gravity Data

Station	Observed gravity after drift correction (milligals)	Elevation (feet)	Elevation correction (milligals)	Latitude correction (milligals)	Terrain correction (milligals)	Complete Bouguer anomaly relative to base = 0 (milligals)
267	285.38	388.0	-1.29	-2.14	0.76	0.68
268	285.81	384.0	-1.55	-2.26	0.70	0.67
269	286.13	380.0	-1.81	-2.39	0.62	0.52
270	286.70	375.0	-2.14	-2.53	0.47	0.48
271	294.15	315.0	-6.02	-3.34	0.14	2.91
272	294.38	317.0	-5.89	-3.27	0.14	3.33
273	294.07	318.0	-5.82	-3.15	0.14	3.21
274	293.90	320.0	-5.70	-3.05	0.14	3.27
275	293.67	322.0	-5.57	-2.97	0.14	3.25
276	293.38	324.0	-5.44	-2.87	0.14	3.19
277	293.33	324.0	-5.44	-2.76	0.14	3.25
278	293.18	324.0	-5.43	-2.65	0.14	3.21
279	292.89	324.0	-5.43	-2.53	0.14	3.04
280	292.75	324.0	-5.44	-2.43	0.15	3.01
281	292.75	322.0	-5.56	-2.33	0.16	3.00
282	292.75	320.0	-5.69	-2.23	0.17	2.97
283	292.81	319.0	-5.76	-2.12	0.18	3.08

Basic Gravity Data

Station	Observed gravity after drift correction (milligals)	Elevation (feet)	Elevation correction (milligals)	Latitude correction (milligals)	Terrain correction (milligals)	Complete Bouguer anomaly relative to base = 0 (milligals)
284	292.56	320.0	-5.69	-2.00	0.18	3.02
285	292.67	320.0	-5.70	-1.91	0.20	3.24
286	292.86	320.0	-5.69	-1.81	0.21	3.55
S-80	249.05	404.20	-0.25	-0.01	1.11	0.28
S-79	249.01	406.46	-0.10	-0.01	1.11	0.39
S-78	248.77	409.22	0.08	0.00	1.12	0.34
S-77	248.58	410.93	0.19	0.01	1.12	0.27
S-76	248.59	412.47	0.29	0.02	1.13	0.40
S-75	248.70	413.43	0.35	0.02	1.13	0.58
S-74	248.51	414.28	0.41	0.04	1.13	0.46
S-73	248.42	415.56	0.49	0.05	1.14	0.47
S-72	248.47	417.28	0.60	0.07	1.14	0.66
S-71	248.38	418.32	0.67	0.08	1.14	0.64
S-70	248.19	419.03	0.72	0.09	1.14	0.51
S-69	248.00	420.17	0.79	0.11	1.15	0.43
S-68	248.01	422.47	0.94	0.13	1.15	0.60
S-67	248.02	424.85	1.09	0.14	1.15	0.78

Basic Gravity Data

Station	Observed gravity after drift correction (milligals)	Elevation (feet)	Elevation correction (milligals)	Latitude correction (milligals)	Terrain correction (milligals)	Complete Bouguer anomaly relative to base = 0 (milligals)
S-66	247.83	427.51	1.27	0.17	1.16	0.80
S-65	247.70	431.08	1.49	0.19	1.17	0.93
S-64	247.41	434.41	1.70	0.22	1.17	0.88
S-63	246.87	438.52	1.98	0.24	1.18	0.65
S-62	246.76	441.43	2.16	0.27	1.18	0.75
S-61	246.76	443.82	2.31	0.31	1.18	0.94
S-60	246.68	446.27	2.48	0.33	1.19	1.06
S-59	246.40	447.37	2.55	0.37	1.19	0.88
S-58	246.08	448.83	2.64	0.39	1.20	0.69
S-57	246.06	449.61	2.70	0.43	1.20	0.76
S-56	246.23	449.91	2.71	0.45	1.20	0.97
S-55	246.06	449.32	2.67	0.47	1.21	0.79
S-54	246.52	447.29	2.54	0.49	1.22	1.14
S-53	246.50	444.72	2.37	0.51	1.22	0.98
S-52	247.06	441.44	2.16	0.53	1.22	1.35
S-51	247.58	438.76	1.99	0.54	1.22	1.70
S-50	247.65	436.76	1.86	0.54	1.23	1.65

Basic Gravity Data

Station	Observed gravity after drift correction (milligals)	Elevation (feet)	Elevation correction (milligals)	Latitude correction (milligals)	Terrain correction (milligals)	Complete Bouguer anomaly relative to base = 0 (milligals)
S-49	248.22	435.51	1.78	0.54	1.24	2.16
S-48	248.25	437.92	1.93	0.55	1.24	2.34
S-47	248.01	439.10	2.01	0.54	1.24	2.18
S-46	248.01	439.60	2.05	0.55	1.25	2.23
S-45	248.21	439.58	2.05	0.55	1.25	2.44
S-44	248.17	438.63	1.99	0.56	1.25	2.34
S-43	248.18	437.83	1.93	0.56	1.25	2.29
S-42	248.48	437.47	1.90	0.56	1.26	2.58
S-41	248.24	437.57	1.91	0.56	1.26	2.35
S-40	248.34	437.97	1.94	0.57	1.27	2.50
S-39	248.15	438.95	2.01	0.58	1.27	2.38
S-38	247.77	441.56	2.17	0.59	1.27	2.18
S-37	247.93	444.56	2.36	0.60	1.28	2.55
S-36	247.59	449.89	2.71	0.61	1.29	2.58
S-35	247.30	456.34	3.13	0.62	1.29	2.72
S-34	247.01	462.54	3.53	0.64	1.30	2.85
S-33	246.58	468.33	3.91	0.64	1.31	2.81

Basic Gravity Data

Station	Observed gravity after drift correction (milligals)	Elevation (feet)	Elevation correction (milligals)	Latitude correction (milligals)	Terrain correction (milligals)	Complete Bouguer anomaly relative to base = 0 (milligals)
S-32	246.21	475.12	4.35	0.66	1.31	2.90
S-31	246.13	481.98	4.78	0.66	1.32	3.27
S-30	246.09	489.13	5.25	0.67	1.32	3.70
S-29	245.85	495.73	5.68	0.67	1.33	3.91
S-28	246.40	501.83	6.07	0.67	1.34	3.83
S-27	246.35	505.33	6.30	0.68	1.35	4.02
S-1	246.26	506.83	6.39	0.68	1.35	4.03
S-2	246.66	502.12	6.09	0.69	1.37	4.15
S-3	247.10	496.74	5.75	0.69	1.38	4.26
S-4	247.45	490.85	5.36	0.70	1.39	4.25
S-5	247.85	484.85	4.97	0.69	1.40	4.26
S-6	248.20	479.20	4.61	0.69	1.41	4.26
S-6	248.50	474.05	4.27	0.69	1.41	4.22
S-8	248.95	468.80	3.93	0.69	1.43	4.35
S-9	249.19	464.17	3.64	0.69	1.45	4.32
S-10	249.54	459.51	3.34	0.68	1.47	4.38
S-11	249.89	455.08	3.05	0.69	1.49	4.46

Basic Gravity Data

Station	Observed gravity after drift correction (milligals)	Elevation (feet)	Elevation correction (milligals)	Latitude correction (milligals)	Terrain correction (milligals)	Complete Bouguer anomaly relative to base = 0 (milligals)
S-12	250.00	451.21	2.79	0.68	1.50	4.32
S-13	250.20	448.15	2.59	0.68	1.51	4.33
S-14	250.54	445.35	2.42	0.68	1.51	4.50
S-15	250.71	444.09	2.33	0.68	1.52	4.59
S-16	250.74	443.21	2.28	0.67	1.53	4.57
S-17	251.06	441.95	2.19	0.67	1.54	4.81
S-18	251.08	439.76	2.05	0.67	1.55	4.70
S-19	251.24	435.89	1.81	0.67	1.56	4.63
S-20	251.55	430.99	1.49	0.68	1.57	4.64
S-21	251.81	427.36	1.25	0.69	1.58	4.68
S-22	252.19	425.41	1.12	0.70	1.58	4.94
S-23	252.40	425.59	1.14	0.70	1.59	5.18
S-24	252.42	427.05	1.24	0.70	1.59	5.29
S-25	252.44	427.68	1.28	0.69	1.60	5.36
S-26	252.42	426.90	1.22	0.69	1.60	5.28
S-129	257.60	426.51	1.19	0.69	1.63	5.41
S-81	258.24	422.88	0.96	0.68	1.66	5.84

Basic Gravity Data

Station	Observed gravity after drift correction (milligals)	Elevation (feet)	Elevation correction (milligals)	Latitude correction (milligals)	Terrain correction (milligals)	Complete Bouguer anomaly relative to base = 0 (milligals)
S-82	258.14	420.90	0.84	0.68	1.69	5.64
S-83	258.93	418.93	0.71	0.67	1.72	6.32
S-84	259.67	414.65	0.43	0.66	1.75	6.81
S-85	260.51	412.27	0.27	0.65	1.78	7.51
S-86	260.86	411.53	0.22	0.64	1.81	7.83
S-104	257.94	406.00	0.13	-1.60	0.95	0.99
S-103	257.71	405.97	0.13	-1.51	0.97	0.86
S-102	257.67	408.21	0.00	-1.47	1.01	1.05
S-101	257.29	412.95	0.32	-1.43	1.04	1.05
S-100	257.29	416.73	0.57	-1.37	1.06	1.37
S-99	256.91	419.22	0.73	-1.32	1.08	1.22
S-98	256.58	423.38	0.99	-1.27	1.08	1.21
S-97	255.99	424.07	1.04	-1.21	1.09	0.74
S-96	255.96	426.61	1.20	-1.15	1.10	0.94
S-95	255.77	427.35	1.25	-1.09	1.10	0.85
S-94	255.58	428.63	1.33	-1.05	1.11	0.80
S-93	255.49	427.00	1.23	-1.00	1.13	0.67

Basic Gravity Data

Station	Observed gravity after drift correction (milligals)	Elevation (feet)	Elevation correction (milligals)	Latitude correction (milligals)	Terrain correction (milligals)	Complete Bouguer anomaly relative to base = 0 (milligals)
S-92	255.15	428.40	1.32	-0.95	1.15	0.50
S-91	255.02	427.75	1.27	-0.91	1.16	0.37
S-90	255.17	430.55	1.46	-0.87	1.17	0.75
S-89	255.37	433.62	1.66	-0.81	1.20	1.25
S-88	255.43	436.21	1.83	-0.78	1.23	1.54
S-87	255.49	439.50	2.04	-0.73	1.25	1.88

Appendix B

Location of earthquake epicenters near Arroyo Seco

Plate 1 Reference Number	**Minutes** 36 Degrees N. Lattitude	**Minutes** 121 Degrees W. Longitude	**Depth** Kilometers	**Richter Magnitude** (Ni = No information)
1	18.46	17.92	8.31	1.60
2	18.64	18.46	8.75	1.40
3	22.01	12.45	6.86	1.80
4	16.33	21.56	5.04	1.60
5	16.56	19.24	6.50	1.40
6	19.48	19.72	10.62	1.40
7	21.02	15.46	5.72	1.40
8	22.27	20.16	7.36	1.10
9	21.16	17.94	11.32	Ni
10	20.85	20.05	10.21	1.00
11	21.98	18.03	8.14	1.60
12	18.71	18.66	8.64	1.50
13	19.12	21.77	8.10	2.40
14	19.38	17.87	9.81	1.10
15	18.33	19.35	4.73	Ni
16	19.48	19.63	10.13	1.20
17	20.91	13.61	13.08	0.50

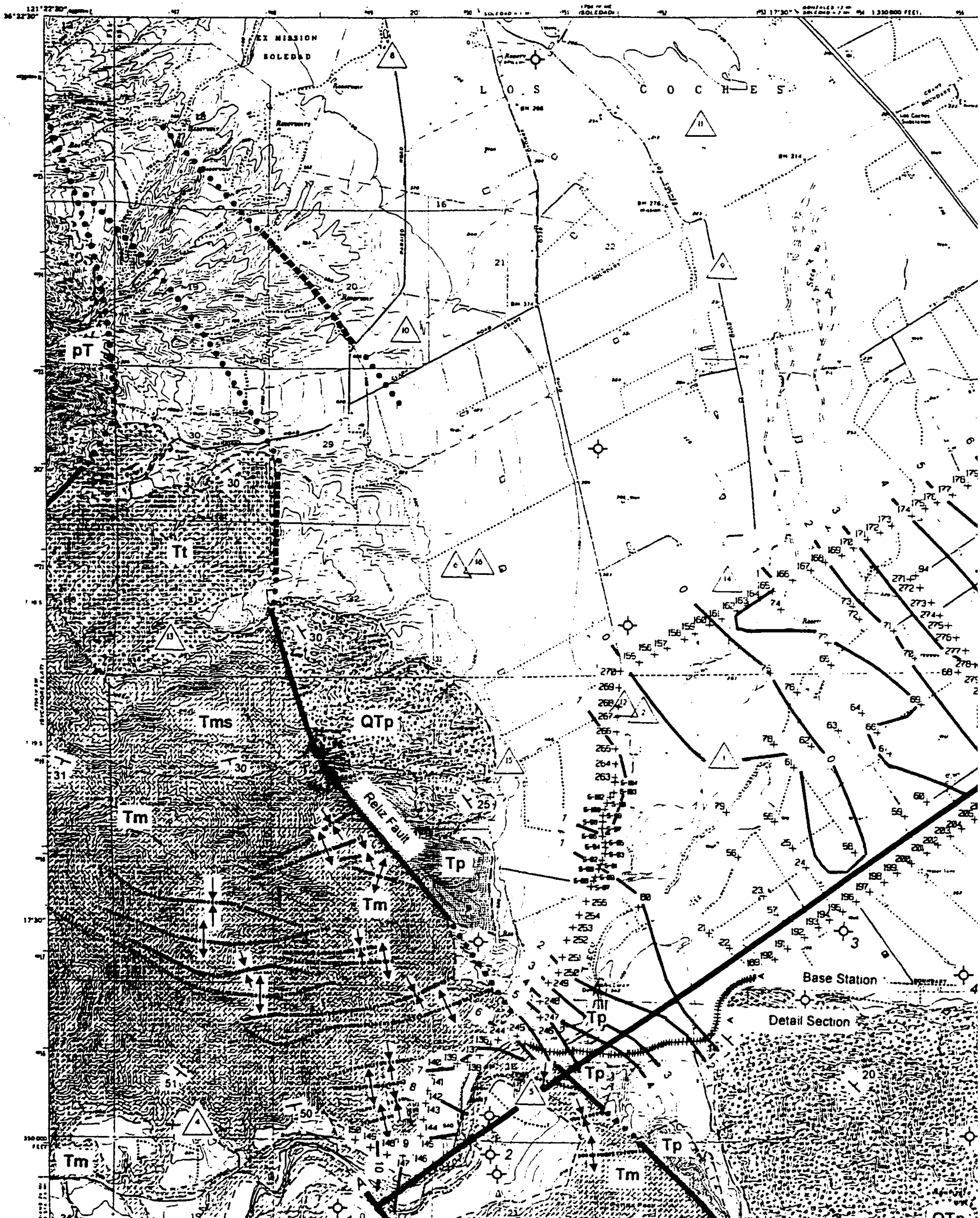
PLEASE NOTE:

Oversize maps and charts are filmed in sections in the following manner:

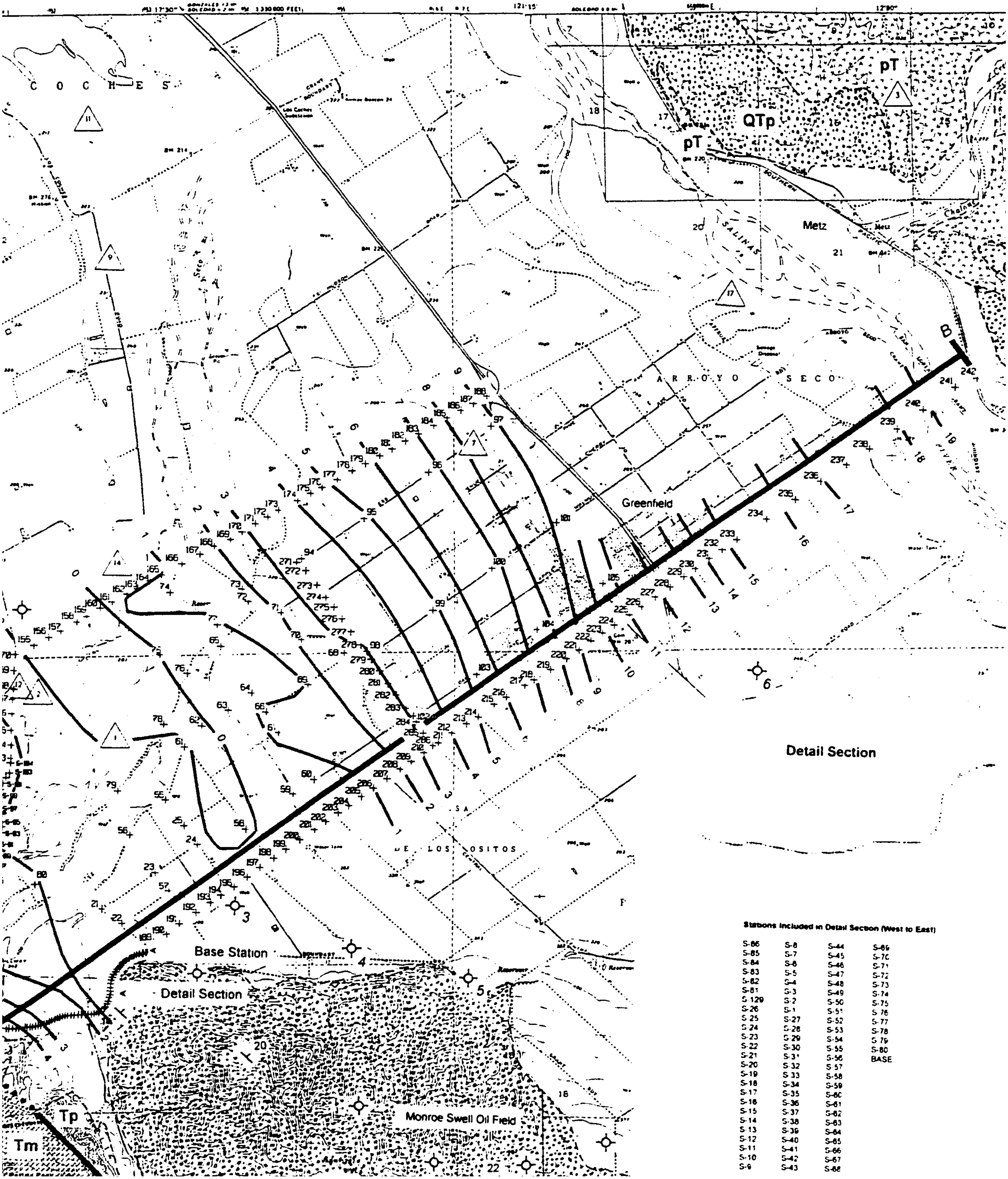
LEFT TO RIGHT, TOP TO BOTTOM, WITH SMALL OVERLAPS

The following map or chart has been refilmed in its entirety at the end of this dissertation (not available on microfiche). A xerographic reproduction has been provided for paper copies and is inserted into the inside of the back cover.

Black and white photographic prints (17" x 23") are available for an additional charge.



MISSION SOLEDAD
L O S C O C H E S
pT
Tt
Tms
QTp
Tm
Reliz Fault
Tp
Base Station
Detail Section



Stations Included in Detail Section (West to East)

S-86	S-8	S-44	S-69
S-85	S-7	S-45	S-70
S-84	S-6	S-46	S-71
S-83	S-5	S-47	S-72
S-82	S-4	S-48	S-73
S-81	S-3	S-49	S-74
S-129	S-2	S-50	S-75
S-26	S-1	S-51	S-76
S-25	S-27	S-52	S-77
S-24	S-28	S-53	S-78
S-23	S-29	S-54	S-79
S-22	S-30	S-55	S-80
S-21	S-31	S-56	BASE
S-20	S-32	S-57	
S-19	S-33	S-58	
S-18	S-34	S-59	
S-17	S-35	S-60	
S-16	S-36	S-61	
S-15	S-37	S-62	
S-14	S-38	S-63	
S-13	S-39	S-64	
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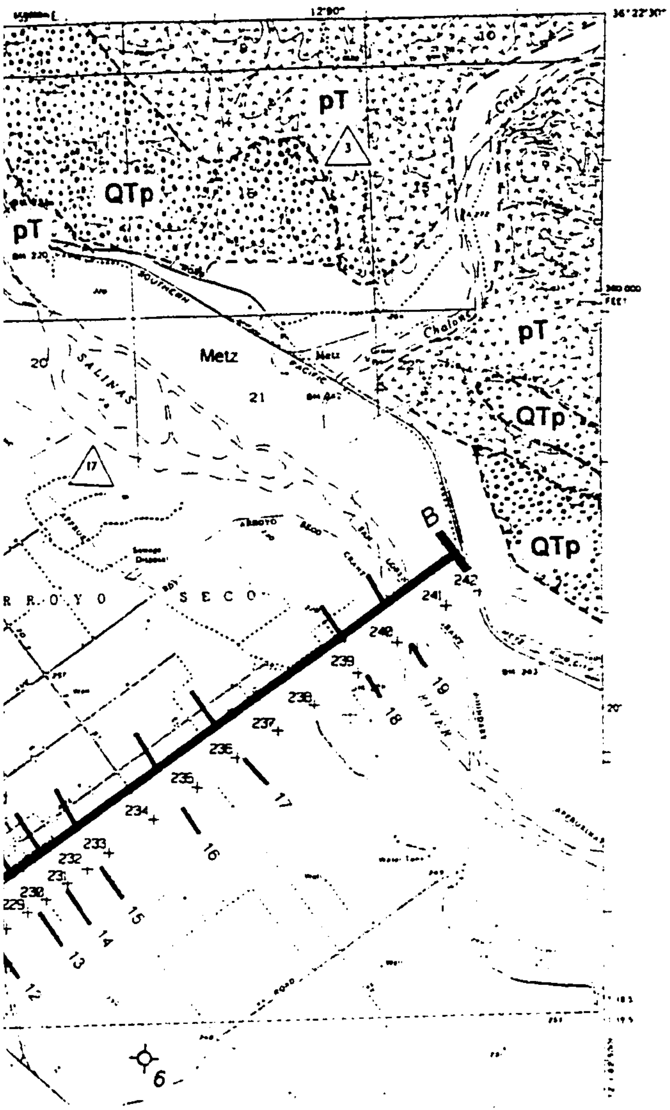


Detail Section

Stations Included in Detail Section (West to East)

S-86	S-8	S-44	S-69
S-85	S-7	S-45	S-70
S-84	S-6	S-46	S-71
S-83	S-5	S-47	S-72
S-82	S-4	S-48	S-73
S-81	S-3	S-49	S-74
S-129	S-2	S-50	S-75
S-26	S-1	S-51	S-76
S-25	S-27	S-52	S-77
S-24	S-28	S-53	S-78
S-23	S-29	S-54	S-79
S-22	S-30	S-55	S-80
S-21	S-31	S-56	BASE
S-20	S-32	S-57	
S-19	S-33	S-58	
S-18	S-34	S-59	
S-17	S-35	S-60	
S-16	S-36	S-61	
S-15	S-37	S-62	
S-14	S-38	S-63	
S-13	S-39	S-64	
S-12	S-40	S-65	
S-11	S-41	S-66	
S-10	S-42	S-67	

EXPLANATION

GEOLOGIC UNITS

Undifferentiated alluvium, old alluvium, fanglomerate, and debris-flow material

QTp — Paso Robles Formation

Tp — Pancho Rico Formation

Tm — Monterey Shale (siliceous shale)

Tms — Monterey Shale (semisiliceous shale)

Tt — Tierra Redonda Formation

pT — Pre-Tertiary (undifferentiated basement rocks)

SYMBOLS

Geologic contact, approximately located

Anticline

Syncline

50 — Strike and dip of strata

Fault, dashed where uncertain, dotted where concealed

17 — Location of earthquake epicenter (see appendix for details)

6 — Well drilled for oil (when numbered, refer to text)

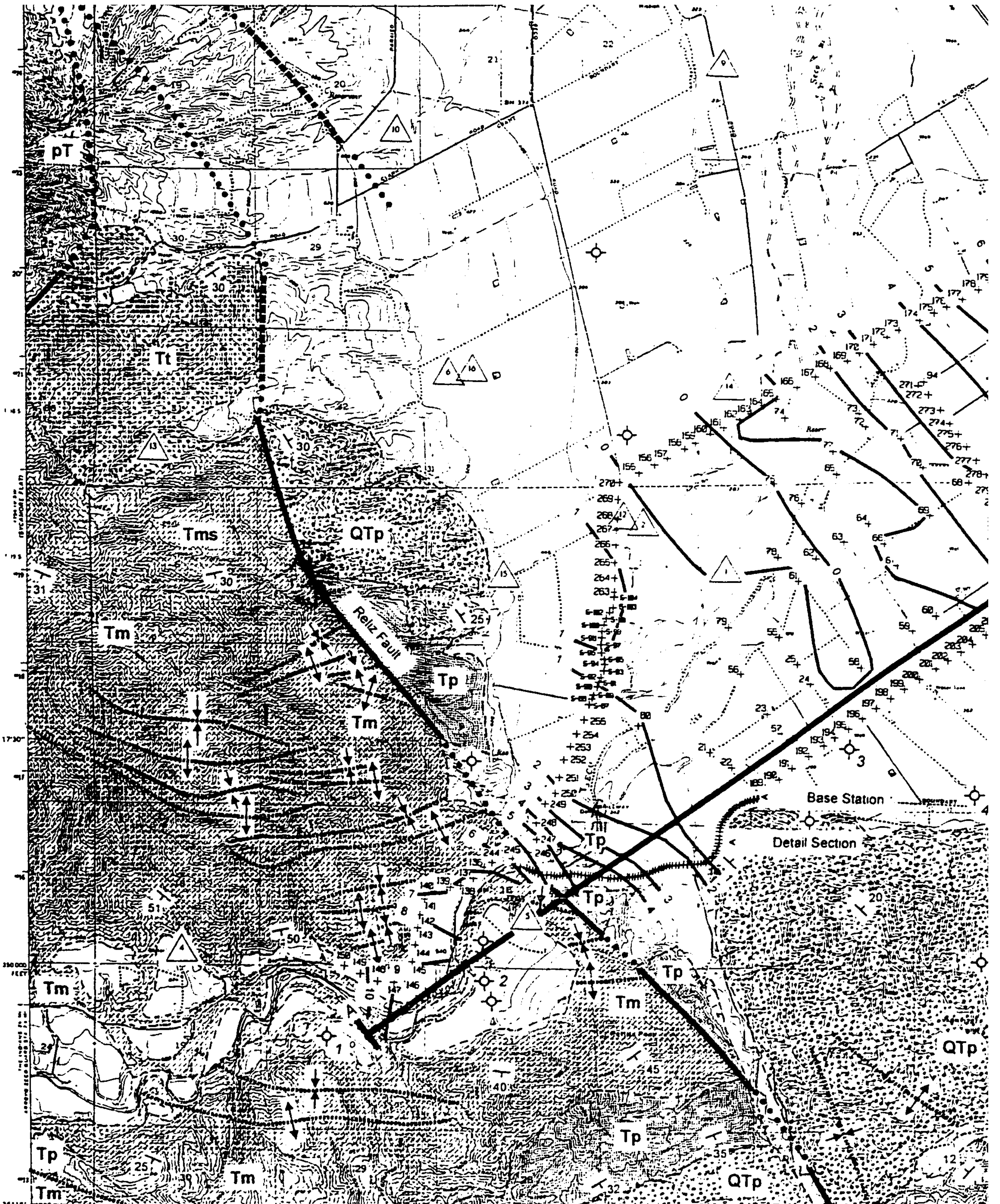
270+ — Gravity station location

19 — Line of equal Bouguer anomaly in milligals (contour interval, 1 milligal)

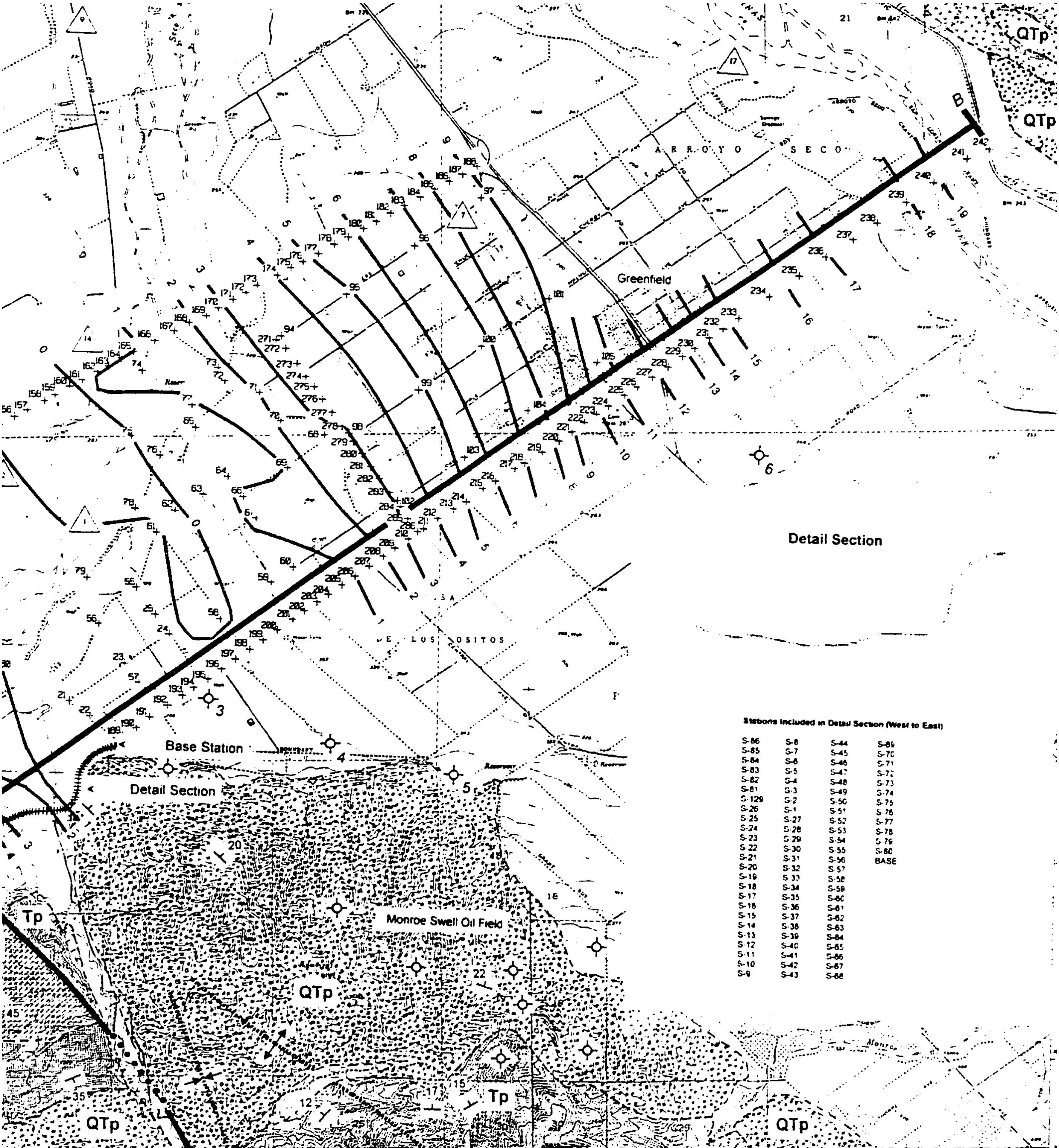
A — Location of gravity and structure section (profile shown on Figures 4 and 5)

REFERENCES

Map Base: U. S. Geol. Survey, 1:24,000 (topographic), Paraiso Springs, CA. and Greenfield, CA. (western portion), both maps 1956,



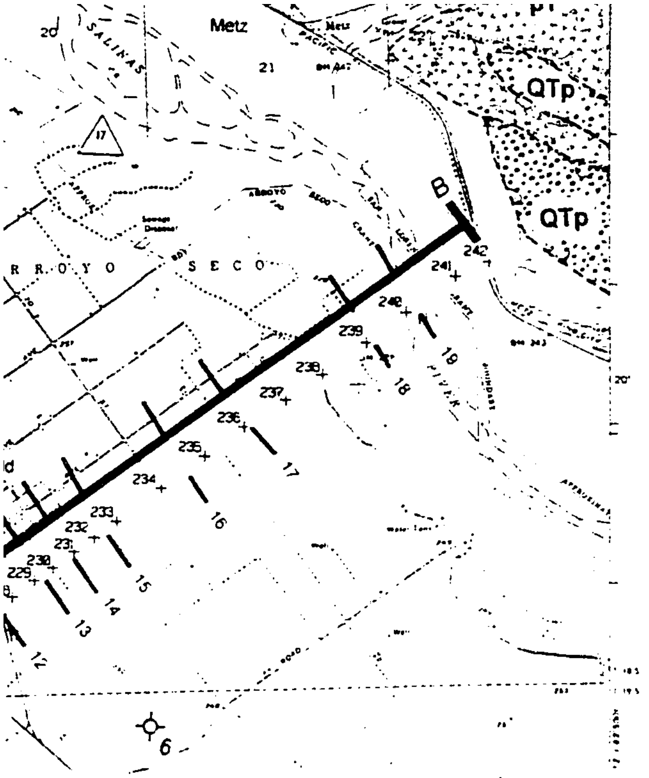
GEOPHYSICAL MAP OF
MONTEREY COU
PLA



Stations Included in Detail Section (West to East)

S-86	S-8	S-44	S-69
S-85	S-7	S-45	S-70
S-84	S-6	S-46	S-71
S-83	S-5	S-47	S-72
S-82	S-4	S-48	S-73
S-81	S-3	S-49	S-74
S-129	S-2	S-50	S-75
S-26	S-1	S-51	S-76
S-25	S-27	S-52	S-77
S-24	S-28	S-53	S-78
S-23	S-29	S-54	S-79
S-22	S-30	S-55	S-80
S-21	S-31	S-56	BASE
S-20	S-32	S-57	
S-19	S-33	S-58	
S-18	S-34	S-59	
S-17	S-35	S-60	
S-16	S-36	S-61	
S-15	S-37	S-62	
S-14	S-38	S-63	
S-13	S-39	S-64	
S-12	S-40	S-65	
S-11	S-41	S-66	
S-10	S-42	S-67	
S-9	S-43	S-68	

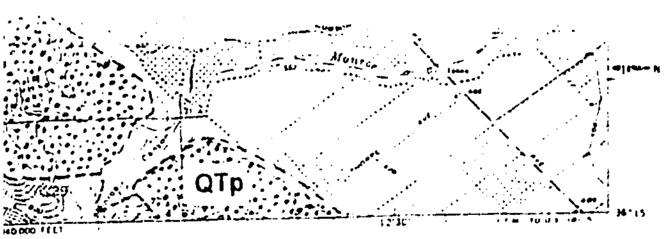
GEOPHYSICAL MAP OF THE ARROYO SECO AREA
MONTEREY COUNTY, CALIFORNIA
PLATE 1



Detail Section

Stations Included in Detail Section (West to East)

S-86	S-8	S-44	S-69
S-85	S-7	S-45	S-70
S-84	S-6	S-46	S-71
S-83	S-5	S-47	S-72
S-82	S-4	S-48	S-73
S-81	S-3	S-49	S-74
S-129	S-2	S-50	S-75
S-26	S-1	S-51	S-76
S-25	S-27	S-52	S-77
S-24	S-28	S-53	S-78
S-23	S-29	S-54	S-79
S-22	S-30	S-55	S-80
S-21	S-31	S-56	BASE
S-20	S-32	S-57	
S-19	S-33	S-58	
S-18	S-34	S-59	
S-17	S-35	S-60	
S-16	S-36	S-61	
S-15	S-37	S-62	
S-14	S-38	S-63	
S-13	S-39	S-64	
S-12	S-40	S-65	
S-11	S-41	S-66	
S-10	S-42	S-67	
S-9	S-43	S-68	



Paso Robles Formation

Tp Pancho Rico Formation

Tm Monterey Shale (siliceous shale)

Tms Monterey Shale (semisiliceous shale)

Tt Tierra Redonda Formation

pT Pre-Tertiary (undifferentiated basement rocks)

SYMBOLS

Geologic contact, approximately located

Anticline

Syncline

50 Strike and dip of strata

Fault, dashed where uncertain, dotted where concealed

17 Location of earthquake epicenter (see appendix for details)

6 Well drilled for oil (when numbered, refer to text)

270+ Gravity station location

19 Line of equal Bouguer anomaly in milligals (contour interval, 1 milligal)

A Location of gravity and structure section (profile shown on Figures 4 and 5)

REFERENCES

Map Base: U. S. Geol. Survey, 1:24,000 (topographic), Paraiso Springs, CA. and Greenfield, CA. (western portion), both maps 1956, Paraiso Springs photorevised, 1984.

Geology: Geological map after Dibblee, 1974 and Durham, 1970.